8-2022

An analysis of public comments on the implementation of the NGSS in Kentucky.

Matthew David Trzaskus
University of Louisville

AN ANALYSIS OF PUBLIC COMMENTS ON THE IMPLEMENTATION OF THE NGSS IN KENTUCKY

By

Matthew David Trzaskus
B.S., Clemson University, 2001
M.A.T., University of Louisville, 2015

A Dissertation
Submitted to the Faculty of the
College of Education and Human Development
In Partial Fulfillment of the Requirements
for the Degree of

Doctor of Philosophy
in Curriculum and Instruction

Department of Elementary, Middle and Secondary Education
University of Louisville
Louisville, Kentucky

August 2022

AN ANALYSIS OF PUBLIC COMMENTS ON THE IMPLEMENTATION OF THE NGSS IN KENTUCKY

By

Matthew David Trzaskus

B.S., Clemson University, 2001

M.A.T., University of Louisville, 2015

A Dissertation Approved on

August 10, 2022

by the following Dissertation Committee:

Thomas Tretter, Chair

Justin McFadden, Co-Chair

Elisabeth Ann Larsen

Marco Munoz

DEDICATION

This Dissertation is dedicated to my wife,

Kitty

Who supported me and never allowed me to give up on this journey.

And my children,

Alexis and Theo

Who light up my days with their amazing kindness, my work is for you

ACKNOWLEDGEMENTS

The list of individuals I would like to acknowledge for this dissertation would be longer than the dissertation itself. I have received so much support from family and friends, mentors and colleagues, students and teachers. Words of wisdom, perspective, and life experiences influenced my understandings and sharpened my focus. I am so appreciative of the participants of this study, all of whom sacrificed their time in order to voice their opinion.

I would also like to acknowledge my committee. Dr. Justin McFadden, pushed my thinking in directions I did not know I had, and pulled the best out of me with his support. Dr. Tom Tretter, challenged me to focus on the minutia while never missing the larger picture. His willingness to give as much time as I needed, did not go unnoticed. To Dr. Ann Larson who always provided the most complimentary affirmations no matter how I felt during the process. To Dr. Sheron Mark who provided confidence in me to participate in, write, and present research which I feel is so impactful. Last, but in no means least, Dr. Marco Munoz, who provided timely advice and provided a practical focus for my research and reminded me of who my work is really meant to impact, students.

Finally, I do want to acknowledge my family. To my parents who provided me with so many opportunities, I hope you can see the fruits of your sacrifices. To my amazing wife, words cannot describe all you have done for me during this process. Even

through all your efforts the most amazing parts shine through, your ability to provide for the children and help them grow. To you I owe most of all.

ABSTRACT

AN ANALYSIS OF PUBLIC COMMENTS ON THE IMPLEMENTATION OF THE NGSS IN KENTUCKY

Matthew Trzaskus

August 10, 2022

Feedback has been a highly effective means to enact change. In the classroom teachers provide feedback to students concerning their performance, how they compare to the learning goal, and what students need to achieve those goals. For teachers, they utilize feedback from students to examine content focus and instructional practice in order to reflect and make positive changes.

In this study, feedback is once again provided in order to enact change. Kentucky stakeholders, mainly teachers, in science education offered feedback about the implementation of the Next Generation Science Standards (NGSS). In their feedback they highlighted the challenges that occurred after reflecting on the classroom practice. Teacher comments called into question some of the content focus of the standards as well as sometimes the application of the standard. Teachers informed authors of the standards by questioning the lack of resources, the standards are not clear to students, and some of them perceived no coherent way to align and teach the standards.

The overwhelming majority of teacher feedback provided was negative which is likely due to sampling bias in that those with negative perceptions are more likely to volunteer comments than those with positive. However, they also offered suggestions for the NGSS to be improved. Teachers asked for specific resources, such as, assistive

technology, data for instruction, and targeted professional development to understand science and engineering practices. Also teachers stressed the importance of a coherent approachable science storyline, scaffolding language for students, and creating a climate of achievement for students.

I was able to frame the study within my subjectivities which matched the most common participants' experiences, in order to make meaning of the data. To further the trustworthiness of the study, a constructed grounded theory approach was used. This approach is appropriate to discover emerging themes in the public comment data, compare and organize those themes, and to create explicit hypotheses of participants' comments.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURES PAGE

CHAPTER I

INTRODUCTION

In the field of science education, fostering scientific literacy in students has been central to the science education community for well over thirty years (American Association for the Advancement of Science, 1989):

> “Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives ... The world has changed in such a way that science literacy has become necessary for everyone, not just a privileged few: science education will have to change to make that possible" (p xiii-xvi, AAAS, 1989).

However, in the United States scientific literacy has not been realized for all students, as achievement scores continue to show a persistent scientific literacy gap (Hwang, Choi, Bae, & Shin, 2018; Lee & Buxton, 2008; Matthews, 2000). In fact, due to a lack of exposure to science, many K-12 students do not feel equipped to become part of the science workforce (National Research Council, 2009).

This was echoed by the National Academy of Sciences report, *Science Teacher Learning*, stating students lack “sufficiently rich” experiences with the content taught (Wilson, 2015). Duggar, (2014), suggests “doing science,” as scientists would, through constructing arguments, modeling, and analysis of data, can support students’ engagement in the classroom (Berland et al., 2016; Geier et al., 2008; Kuhn, Hemberger, & Khait, 2017 Wilson, Taylor, Kowalski, & Carlson, 2010). Providing meaningful lessons is a primary assumption for NGSS and the Framework as the aim is to create meaning for students in science (Cobern, 1996; Cobern, 2000; Seymour, 2002; Smith & Nadelson, 2017).

NGSS aims to bring meaning

Teachers must translate standards to curriculum, classroom practice, and assessment which shapes how students gain knowledge, skills, and abilities as described in the standards (Marzano, 1999; Marzano, 2003; McTighe & Wiggins, 2012). Standards describe what students should know and be able to do within a particular content area (Stein, 2000). Often teachers are not provided with the appropriate support to translate standards and therefore they rely on the curriculum given to them (Marzano, 2003; Olson 2018). If teachers are prescribed a curriculum by their district, they may be ineffective at implementing the standards due to a lack of ability or support (Abell et al., 2009; Marzano, 2003). This lack of ability can lead teachers to conflate standards with curriculum as the same (Tomlinson, 2000; Olsen 2018). This is due to the teacher's inability to recognize the intent of the standard when planning lessons (Tomlinson, 2000). Barnette (2003) cautions that, "Trying to make the lessons fit into the standards generally results in a curriculum that merely reflects the standards (pg. 32)," but does not match the standard's intent. Claiming lessons to be standard based when they are not, teachers can miss the intent of the standard (National Research Council, 2001). In fact, reverse translation of making lessons fit the standards was common practice when the NGSS were first released (Seljan, 2016). Teachers analyzed their lessons and activities, compared them to a group of standards, found potential similarities, and assumed their curriculum and practices were standards-based (Sleeter & Carmona, 2017; Sleeter & Zavala, 2020). By merely claiming their lessons were standards-based, teachers failed to give opportunities for students to engage in science practices (Lotter, Thompson, Dickenson, Smiley, Blue,& Rea, 2018.). However, when teachers adapted their lessons to fit the needs of their students they were more successful in creating science opportunities (McLaughlin & Talbert, 1993; Siskin, 2014).

One way to gain insight to teacher learning experiences is obtaining feedback from them (Chapple & Murphy, 1996; Chin, 2004). In fact, teacher voice was utilized in the creation of the NGSS, which was a new aspect of standards reform. The feedback provided by teachers regarding their local adaptations lead to a refocus in the standards (Huizinga et al., 2014; Yurkofsky, Peterson, Mehta, Horwitz-Willis, & Frumin, 2020). Local adaptations, or culturally relevant instruction, are a warranted and essential aspect of teaching practice and an appropriate teacher implementation of standards providing opportunities for students to engage in science practices (Venville, Sheffield, Rennie, & Wallace, 2008). Scaffolding instruction in a culturally relevant fashion is one of many possibilities when standards are translated into curriculum and classroom practice, although this is challenging to accomplish (Kazemi & Hubbard, 2008). Often teachers enact lessons to the best of their abilities, reflect on their practice, and adjust their instruction to fit their students' needs (Cross, 2009; Darling-Hammond & Baratz-Snowden, 2007). Knowing that teachers attempt to enact curriculum to fit their students' needs, illustrates the importance of examining teachers' learning experiences as they engage with the standards and translate them to curriculum and classroom practice.

Teachers and feedback

Despite being largely left out of conversations concerning curriculum development, teachers have shown positive effects on curriculum in response to their feedback (Drew, Priestly, & Michael, 2016); especially when the aim is to improve student learning outcomes (DeLuca et al., 2015). Researchers have adjusted materials to better serve the students and teachers after receiving comments when teachers were "uncertain how to make and engage students in this (making evidence-based claims) practice" (Elliott, 2011, p. 297). Bismack, Arias, Davis, and Palinscar (2015) enhanced a 4th grade unit to increase support for three science practices (making observations, making predictions, and making evidence-based claims), by utilizing the feedback of participant teachers. In the same line of listening to teacher feedback, AAAS and Biological Science Curriculum Study developed the Toward High School Biology unit. Throughout a multi-year cycle of curriculum roll out, developers listened to feedback from their participant teachers to hone the educative curriculum (Herrmann-Abell, Koppal, & Roseman, 2016). These studies show based on teacher feedback post lesson enactment are important to creating positive teacher interpretations of the standards. While these studies relate to curriculum materials, teacher feedback has shown more recently to be an aspect of public policy (Schwab, 2018).

Many states have enacted a feedback mechanism to include teachers in the process of evaluating standards. In Kentucky, recent legislation asked all stakeholders to comment on standards on a rotating basis. The NGSS was selected to be reviewed in 2021 as part of this cycle of standard review through the use of public comments. The public comments were the first time the NGSS was subject to this type of feedback by

Kentucky education stakeholders. One could infer, teachers would have little to no training on providing feedback regarding implementation of standards. Consequently, analyzing the feedback regarding teacher challenges of implementing NGSS, becomes a significant starting point to determine the standards' effectiveness as viewed in the classroom.

Feedback which begins with Public Opinion

Public opinions are a valuable source of data which can be used to empirically examine how government agencies interact with the public (Mendleson, 2011). As a form of political participation, publicly expressed views by individuals or groups provide information to agencies in order to potentially shape their actions (Yackee, 2005). The public opinion process has become a forum for both individuals and interest groups to debate policy (Dahlberg, 2001). In recent years, the interest in rulemaking and agency actions has increased; therefore, government agencies receive millions of opinions on their actions regarding policy (DeMuth, 2018). In the realm of education; however, public comments have not been sought out frequently (Kuhlthau, 1991; Strasser et al., 2019). Often focus groups made up of researchers and policy analysts are asked to provide their expertise concerning educational policy (Brown, 2015). Teachers are often left out of the discussion and not believed to be experts in curriculum, but merely practitioners (Berliner, 1988; Park & Oliver, 2008; Prawat, 2001; Sawyer, 2004). However, the states using the NGSS relied on teachers' expertise in curriculum and had teachers partake in the comment process offering their feedback on standards (Haag & Meadowen, 2018).

Feedback is a more focused type of public opinion illustrated by the individual's knowledge on the subject in which they provide their opinion (Soroka & Wlezien, 2010). In general, the comment is considered feedback when an individual is a stakeholder, an informed participant in the policy process, and who believes their opinion is the best representation of a policy (Renn et al., 1993). A common practice in business, policy feedback is obtained from stakeholders' opinions, typically negative since those with negative opinions are more incentivized to comment than those with strictly positive views, when they believe policies do not serve their needs (Pikkareinen, 2021).Some feedback also provides potential suggestions for improvement (Williams, McMurray, Kurz, & Lambert, 2015). Furthermore, stakeholders, including ones in education, have greater tendency to provide more feedback when the process is anonymous (Clayton, 1997). Tsai & Gasevic (2017) found in higher education, anonymous opinions regarding challenges with a policy should be examined, as the feedback has merits. Although not specific to teachers, feedback, hence, is influential for policymakers as teachers are knowledgeable stakeholders, because their feedback comes from the utilization of their knowledge, and is targeted at the policy which aligns with their knowledge (Deverka et al., 2013).

Scope of the Study

Teachers are asked to promote deep science learning for all students through active engagement and application of contextualized knowledge. One of the main focuses of the NGSS is to promote deep science learning by creating opportunities for students to engage in scientific practices (NGSS Lead States, 2013). This study seeks to explore the resulting challenges teachers wish to make known through anonymous comments in a public survey to policy and curriculum makers, researchers, and other stakeholders regarding the NGSS and the implementation of the standards. For the purpose of this study stakeholders include teachers, retired teachers, administrators, district resource personnel, and parents which were all potential participants within the sample. However, teachers were by far the largest response group demographic; therefore, teacher voice is the lens by which the analysis proceeds.

The study analyzed the public comments made by various stakeholders concerning the implementation of the NGSS in Kentucky classrooms. The comments were obtained from a government survey open to all education stakeholders as part of a process to review standards for alignment and recommended changes. Patterns in the comments are displayed, organized and merged to form an argument as to what teachers are stating are the challenges of NGSS and their recommendations for improving the NGSS. Ultimately, the study can inform policy makers, curriculum designers, school administrators, and other teachers as to the challenges of teacher implementation of the NGSS. This study is an analysis of these public comments from teachers in which the following research questions were asked:

1. What comments are conveyed via public survey by teachers regarding the implementation of the Next Generation Science Standards?
2. What suggestions for improvement were given by teachers to alleviate the challenges they have seen regarding implementation?

Through these questions the study aims to investigate how positive changes in learning can occur through increased teacher voice in the decisions of curriculum and standards enactment.

CHAPTER II

LITERATURE REVIEW

The literature review will provide a grounding of the iterative nature of science reform which is vital to understand the applicability of the study's data set regarding the NGSS. First, the importance of public opinion's impact on influencing policy is given. Next, how teachers utilize reflection in their practice. This reflective practice leads to moving beyond an opinion to the ability to give meaningful feedback about policy. Then, I will illustrate how science education standards have been influenced from public opinion prior to the creation of the NGSS. The NGSS, unlike prior standard reforms, utilized teacher feedback intentionally as a means to hone standards. Finally, I connect the importance of teacher feedback with the comments of the study's data set as the focus of the study.

Public Opinion as a Means to Influence Policy

In a democratic society, policy created reflects the wishes of the people within that democracy. The will and influence of the people on policy is subtle to the casual observer who would believe large lobbying groups hold higher amounts of influence on policy (Henry & Mark, 2003). In fact, the power of public feedback far outweighs the influence of corporations due to an individual's ability to vote for the policymakers (Dalton, 2013).

Feedback differs from public opinion by how much the individual is informed on the subject in which they provide their opinion (Soroka & Wlezien, 2010). Feedback requires an individual to be a stakeholder, an informed participant in the policy process, who believes their opinion is the best representation of a policy (Renn et al., 1993). Feedback can be collected in many forms from stakeholders, and the more expertise the stakeholders have in the subject matter the more influential their feedback becomes. When stakeholders believe the policy does not serve their needs they provide more feedback and potential suggestions for improvement (Williams, McMurray, Kurz, & Lambert, 2015). Individual stakeholder feedback, hence, is influential for policymakers if the stakeholder is knowledgeable, the feedback comes from the utilization of the knowledge the stakeholder possesses, and is targeted at the policy which aligns with their knowledge (Deverka et al., 2013).

Teacher Reflective Practice

In conjunction with interpretation and enactment, a mediating step of reflection drives the local adaptations of teaching content (Cross, 2009). In this section of the review, I discuss how reflective practice is used by teachers, and why this is an intermediary step between instruction and feedback.

Defining Reflective Practice

Dewey (1933) suggested that reflective thinking originates from a state of doubt or confusion, which can lead to a search for answers or a resolution to a problem. He defined reflection as:

> . . .active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and further conclusions to

> which it leads … it includes a conscious and voluntary effort to establish belief upon a firm basis of evidence and rationality. (p. 9)

Teachers engage in reflection, after, and sometimes during, lessons in order to help rectify their difficulties in teaching the content (Farrell, 2013). Reflection depends upon the formation of reasons why students develop certain thoughts about content and how teachers can improve the connections students make (Dewey, 1933). In this way reflective thinking is active, persistent, and contemplative, and, as such, reflection should be intentional (Dewey, 2014). Through this intentionality, teachers can generate adaptive knowledge rather than be passive receivers of it (Bruner, 1986).

Reflection and teacher use in instruction

The action of reflection represents the human capacity for higher-level thinking and our ability to assign meaning to our experiences (Denton, 2009). Through reflection teachers assign meaning to their classroom experience as they examine their success and challenges they had with the content (Fantilli & McDougal, 2009). Upon reflection teachers alter their lessons, most often to check for student understanding, through formative assessment (Dewey, 1997). However, sometimes, teachers examine multiple constructs such as their experience, content knowledge, and pedagogical practices (Gess-Newsome, 1999; Gess-Newsome et al., 2019; Hill, Ball, & Schilling, 2008). Teachers who examine multiple constructs after a lesson, may alter their lessons in the hope of improving instruction (Dudley, 2013).

As teachers alter their lessons, the process of reflection remains intentional for them even after the second, third, and beyond iterations of lessons (Dewey, 1997). As teachers begin to become more adept at teaching content in ways that meet their students' needs, they are better able to verbalize their successes and challenges (Darling-Hammond, 2006). In this respect, challenges may lead to frustration with aspects of education, such as resources or creation of standards, which are beyond the control of the classroom teacher. Feedback about these aspects of teacher education is critical in understanding the struggles teachers have in the classroom regarding the content they teach and the needs they have (Kyriacou, 2001). Although critical in nature, the reflection of teachers has a positive focus to improve the quality of lessons, instruction, and positively affect student learning, specifically if they share their concerns as feedback to policy makers.

Importance of Feedback

Feedback is an important part of the learning process. Research has already established the merits of feedback on learning. It has been described as the most powerful factor which positively affects learning (Hattie & Timperley, 2007; Sadler, 1989; Stobart, 2006; William, 2011). Feedback can be focused on standards effectiveness based on direct observation and knowledge of the classroom environment (Regan-Smith, Hirschmann, & Lobst 2007). One of the main aims of teachers providing feedback is to help close the gap between what is understood and what is currently being achieved by students (McMillan, 2010). Through this lens teachers can provide effective feedback to creators of standards to highlight gaps in student understanding. This type of feedback can occur when the happenings of the classroom, both positive and negative, are provided to those who create standards (Harlen & James, 1997; Torrance, 1993).

Using Feedback to Hone Standards

Historically, teachers and practicing professionals did not provide feedback to hone science standards (Aronson & Laughter, 2016). Instead, educational researchers and policy creators took on this challenge, often relying on their knowledge base and public opinion in response to international events and student achievement (DeBoer, 2000; Hurd, 2002; Leshner, & Scherer, 2019). Not until the creation of the NGSS did standard creators purposefully provide teachers with a voice concerning the standards they were being asked to implement (McFadden & Roehrig, 2017; Remillard, 2005).

Development of US science standards

In 1956 science education reform took a substantial step forward when Jerrold Zacharias began the Physical Science Study Committee; however, less than a year later Sputnik was launched and the movement of science reform became a national issue (DeBoer, 2000). Linked to the public's fears associated with a Soviet takeover, the United States felt a great need to push science education to new heights. With this impetus and spurred by Kennedy's rousing words of choosing to go to the moon through being bold, the United States succeeded in landing on the moon in 1969 (Johnson-Freese, 2007). The moon landing was perpetuated by the public's opinion for a need for a national focus on science, which pushed science education to be more predominant throughout the 1960s.

Despite some successful reforms in science education in the United States, desired instructional shifts have often failed to take place (DeBoer, 2000). In retrospect, perhaps the need for iteration educational reform was due to the lack of coordination and common focus of a national goal for science education (National Research Council, Committee on Prospering in the Global Economy of the 21st Century, 2007; Washington, Barish, Droege-Meier, & Ford, 2006). To achieve the goal, varying public opinions of specific recommendations to engage in reform differ; however, both shared the idea which emphasized students' understanding of science, and science learning should be standardized. As the term standards was not a term in science education until the late 1980s, there remained a lot of disagreement on how standardization could be achieved (Lederman, 1999). To illustrate, the publication of *Science for All Americans* (AAAS, 1989) advocated the need for the U.S. citizenry to achieve scientific literacy prior to the year 2061 (Wilson, 2015). The term scientific literacy has multiple facets and definitions, as well as the long timeline given, has allowed science education reform to move at a slow pace (Hubber, Tytlem, & Haslam, 2010).

However slow the pace, the fundamental idea behind science remained in which education standards are to describe clear, consistent, and comprehensive science content and scientific practices (Lederman, 1999). In considering specifically the science education reform of the United States, a highly nationalistic public opinion of being first in world competition drove the creation of science standard development (Czerniak & Lumpe, 1996). Choosing which scientific content and practices were to become the focus of standards, often were the public's reaction to world political or social events (Webb, 2006). Prior to this science education had numerous committee reports, yearbooks, and other publications that served as ‘‘standards,” but were not a formal singular document (Bybee, 2014).

Purpose for creating the NGSS

Developments of the 1960s and 1970s—change from recall to science meaning

The NGSS will have a significant impact on science education moving forward (Pratt, 2013). The common goal of a moon landing during the twelve-year span of the Space Race, had a distinct focus that coupled science with national needs of technological superiority. Prior to Sputnik, the United States science curriculum focused primarily on facts and recall (Herold, 1974). This style of knowledge was insufficient for learners in the classroom as it did not meet students' needs, or the needs of society (DeBoer, 2000). Due to this, science researchers called for a change in the curriculum moving more toward science meaning and aiding in improving society. The call was for scientific literacy, or as the National Science Teachers Association (NSTA) declared students who are scientifically literate will, "use science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment" and they "understand the interrelationships between science, technology and other facets of society, including social and economic development" (NSTA, 1971, pp. 47-48).

Furthering this point in 1960, educational researchers from the National Society for the Study of Education focused on science education in its Fifty-ninth Yearbook entitled *Rethinking Science Education*. In this yearbook it was proposed that the goal of scientific literacy was that science educators should work to produce citizens who understood science and were sympathetic to the work of scientists (NSSE, 1960). Also members of the National Science Federation (NSF) defined science literacy as, ". . . some of the processes used in arriving at conclusions in science have a relevance to our thinking and, indeed, to our behavior in other phases of life," (NSSE, 1960, pg. 24). By collecting and synthesizing the public's opinion of science, national pride, and international events, science content and instructional practice had a common focus that altered science education.

Calls for a scientific literate society

Once the goal of the moon landing was met, confusion over what science's next venture ensued. Throughout the 1970s, science became more of a progressive venture that valued societal problems over nationalistic ones. According to Gallagher, (1971), "For future citizens in a democracy, understanding the interrelations of science, technology, and society may be as important as understanding the concepts and processes of science" (p.337). Over the next decade, American students began to outperform their world peers, not just in science, but in many other subjects. In fact, public attitudes toward science were also becoming more positive (Shymansky, Kyle, & Alport, 1983). The gains in student achievement during the 1970s are attributed to the goal of making science relevant for students' daily lives (Lederman, 1992).

This relevance, although effective to start, had created a new set of challenges as it created a naïve absolutist notion of the nature of science (Lederman, 1992). In fact, during the development of the instrument, Knowledge of the Nature of Science Scale, Rubba (1977) found that students felt that any theory or hypothesis would become scientific law once they were confirmed (Rubba & Anderson, 1978). The naivety of student knowledge led to American students losing ground in science achievement to their world peers. This loss of high test scores created a new set of detractors, mainly educational researchers who echoed public opinions regarding the drop in scores. They espoused that the pursuit of science should be personalized in students' lives and applied to all aspects of their lives (Hofstein & Yager, 1983). This drop in performance was best illustrated by the 1983 work, *A Nation at Risk* (National Commission on Excellence in Education; NCEE) coupling the low performance scores with the economic declines in America.

Developments of the 1980s & 90s—Inclusion of technology in science curricula

The issuance of the report was a major piece of public opinion on the state of science education. In the report, the solution was to create a more rigorous academic curriculum for all students built around the core academic subjects, as well as computer science and foreign language. By including computer science, the focus shifted from scientific literacy to science in society with technology (Lederman, 1992). The movement to include a technological aspect in science would be accompanied by a new national movement for the United States to reassert dominance in these areas (DeBoer, 2000). In 1989, the National Governors Association, responding to the public's opinion of improving in science on the international level, and with President Bush, endorsed the idea of establishing "clear national performance goals" as a way to raise standards in education to "make us internationally competitive" (U.S. Department of Education, 1991). The new comprehensive science reform effort would become known as science-technology- society (STS), where students should be able to identify science-related social issues, analyze the context in which the issues are played out in society, know the key individuals and groups involved in making decisions, investigate these science-related issues themselves, develop an action plan, and implement that plan where appropriate (Ramsey, 1989).

Clarity on scientific literacy and technology integration

Based on this feedback and call to action, the AAAS brought this renewed focus to life with the work 'Science for All Americans' written in 1989. The work encapsulated the previous idea of scientific literacy, and framed it in differing levels of interest; stating science can be clustered around 'major set of related topics' (AAAS, 1989, p. 6). This comprehensive work clarified the goals of science education to ensure all students could be scientifically literate. The clarification came through the blending of science and technology in society as it asked teachers to have students be, "aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes" (AAAS, 1989, p. xvii ± xviii).

The blended model of science and technology did not fully explain what science content should be taught as standard practice (Kelley & Knowles, 2016). In order to enhance the focus of content, throughout the 1990s, opinions were synthesized from national commissions, professional organizations such as the NSTA along with researchers, employers, and university faculty, to hone the focus of science standards (AAAS, 1989, 1993; Boyer Commission, 1998; NRC, 1996; NSF, 1996). The work of science reform continued as the National Academy of Sciences (NAS) took this topical idea and created a set of 'benchmarks' that could determine the scientific literacy of a 12th grade student. This work provided the basis for Benchmarks for Science Literacy

(AAAS, 1993) and prepared the United States for National Science Education Standards (NRC, 1996). The National Research Council (NRC) wished to detail “what students should know, understand, and be able to do in the natural sciences over the course of K-12 education” (NRC, 1996, p.6). From this work, the NRC was able to create a set of concise standards that teachers were to use to interpret scientific literacy.

From science-technology-society to inquiry

Begun in 1992, the National Science Education Standards (1996) justified education reform by having education researchers respond to public opinions with an approach that involved setting national goals and the standards for meeting them. Five main assumptions justified the identification of the content standards: (a) “Everyone needs to use scientific information to make choices that arise every day." (b) “Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology." (c) “Everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world." (d) “More and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions, and solve problems. An understanding of science and the process of science contributes in an essential way to these skills." (e) “To keep pace in global markets, the United States needs to have an equally capable citizenry" (National Research Council, 1996, p. 1-2). With this justification the NRC attempted to solidify the STS model for science education; however, holdouts remained as there were many constituents that worried about creating an all-encompassing definition of science education (Collins, 1998).

Despite the early successes of scientific benchmarks, the all-encompassing aspects of science-technology-society were not well received by the entire public (Collins, 1998). Many in the research field held the opinion that science, especially in the social context, is far too complex for students to grasp (Shamos, 1995). Shamos, an education researcher and theorist, (1995) argued for a scientific awareness through functional literacy which later would be termed inquiry. He posits that science content is not truly necessary but rather the process of science (DeBoer, 2000). Scientific inquiry includes the traditional science processes, but also refers to the combining of these processes with scientific knowledge, scientific reasoning and critical thinking to develop scientific knowledge (Lederman, Lederman, & Antink, 2013). In particular, inquiry is perceived by the public in three different ways (Newman et al., 2004). Educational researchers established inquiry to be a set of skills to be learned by students and combined in the performance of a scientific investigation, and inquiry can also be viewed as a cognitive outcome that students are to achieve (Bybee, Fortenberry, & Walker, 2005).

Developments of the 2000s—Subject Area Accountability reduces importance of science

The consistent amount of infighting among science experts, not teachers, led to a lack of consensus as to what should be included in science standards, and to poor achievement for U.S. students on the world stage which created negative public opinions (Robinson & Lubienski, 2011). The culmination of this lack of achievement was met in the early 2000s, with the No Child Left Behind Act, in which science began to get squeezed out of curriculums across the country especially in elementary schools (NRC, 2011). The pressure of the Act's accountability, in which all students in grades 3–8 are assessed on language arts and mathematics annually, has allocated time and resources toward language arts and mathematics, and, due to limited hours in the school year, diminishing time for science instruction (Spillane, Diamond, Walker, Halverson, & Jita, 2004). Science was taught when time allowed, if at all, and this was typically after testing was complete for the year (Kim & Sunderman, 2005).

Integration of science, technology, and career interests

In response to reducing the importance of science in the classroom, the National Science Board, which is composed of university professors and administrators, called for changing curriculum to better equip students to become scientists and engineers (National Science Federation, 2004). This specific focus, which also added technology as a tool, was well received by the public as a way to regain status on the international stage (Seels & Richie, 2004). Also, by drawing from the notion of design experiments (Brown, 1992; Collins, 1992) and, more recently, design research (Kelly, 2003), science education blended science inquiry with technology to focus on learning outcomes. Furthering this point, integration was achieved by including science literacy and the nature of science to be placed in the new standards (Roberts, 2013). As such, with the integration of engineering, technology, and the nature of science, the modern Next Generation Science Standards had begun.

The integration was not a quick or easy process for science education. There was a very cautious approach in order to see that all stakeholders (including teachers for the first time) were heard (Roberts, 2013). In order to gain all levels of insight a committee was created consisting of nine members of the National Academy of Sciences or National Academy of Engineering and nine members who were learning scientists, educational researchers, educational policymakers, or practitioners (NRC, 2011, Appendix C). In developing what would come to be known as the *Framework*, they drew upon current research on learning, research, and evaluation evidence on standards-based education reform, practitioner experiences, and past and existing efforts relevant to science education standards (Schmidt, Wang, McKnight, 2011).

Using stakeholder feedback to hone standards

In order to obtain further expertise, four design teams were established to conduct preliminary research and develop draft materials for consideration by the full committee (NRC, 2011). Committee work was informed by the philosophy that, while there is need for change in K-12 science education, pushing the system too fast and too far could result in abandonment of the effort (Weiss, Paisley, Smith, Banilower, & Heck, 2004). The design teams were to focus on earth and space science, life science, physical science and engineering and technology. These teams were directed by a leader in each educational content area, and consisted of more practitioners than were on the original blended committee. The operating theory being that the design teams would provide an important level of detailed input, and the committee would be the consensus integrating the four content areas (Keller & Pearson, 2012).

Through the feedback of committees, intent on science reform, the momentum grew as the NRC continued to reform science education with their creation of *A Framework for K-12 Science Education*. The *Framework* served as the basis for the state-developed Next Generation Science Standards (NGSS), which set expectations for what students should know and be able to do (NGSS Lead States, 2013). In this more contemporary view of science education development of what became the NGSS began in 2010.

Creation of the NGSS

Development of the NGSS was a combined process, considering the *Framework* and the work of the twenty-six lead states. The *Framework* provided a solid foundation in current science and learning research on the science concepts all K-12 students should know and the science and engineering practices they should be able to do. The *Framework* describes three dimensions for standards: science and engineering practices, crosscutting concepts, and core ideas in science disciplines. The second phase of the development began as a state-led effort, managed by Achieve, in which twenty-six states pledged to consider adopting the new NGSS. Each state also committed to create a broad-based team of K-12 representatives who would provide feedback on drafts of the standards. Drafts of the standards underwent multiple reviews, including two publicly released drafts, which provided all interested and involved individuals and groups with an opportunity to inform the proposed content and practices as well as the organization of the NGSS. The final NGSS document was developed through the collaborative effort of all twenty-six lead states in cooperation with stakeholders in science, science education, higher education, and business and industry.

This process resulted in a set of rigorous, high-quality K-12 science education standards that passed a final review for fidelity by the NRC. The NRC reviewers, using the vision and content of the framework, evaluated the consistency of the final draft NGSS compared to the framework. Finally, the National Academies Press published the final document (NGSS Lead States, 2013). The state of Kentucky voted to adopt the NGSS in June of 2013 and incorporate it into their Kentucky Academic Standards.

History of the NGSS Summary

Science education reformers advocated for change while acknowledging the current standards they were replacing (Hodson, 2003). The known documented history of science standards was in response to various stakeholder feedback (researchers, teachers, politicians, and practitioners all played a role) and influenced by American nationalism. Feedback remained at the heart of the process of change while national ambition surrounded the overall process of shifting content focus and instruction. Feedback has been provided by various stakeholders as various reform efforts in the classroom have changed from one of scientific literacy to science-technology-society to inquiry, and finally integration. Additionally, external influences have also played a role in changing content focus and instruction in classrooms (e.g. ranging from the Space Race to No Child Left Behind). Finally, the NGSS ensured teacher feedback was utilized in order to create the standards currently used in classrooms.

Teacher Implementation of the NGSS

Introduction

In order to be recognized as feedback instead of public opinion an intermediary step of involvement with the subject must take place (Soroka & Wlezien, 2010). An organized approach to collecting an opinion from knowledgeable stakeholders has been a mechanism for states seeking true feedback on standards (Marzuki, 2015) Teacher implementation is an important aspect of gaining teacher feedback of standard effectiveness as it can vary by individual (Gehrke, Cocchiarella, Harris, & Puckett, 2014). Prior interpretation of the intent of the standards results in specific enactment of instruction, and teacher feedback typically comes after reflection of the classroom experience (Kelcherman, 2009). In fact, out of curriculum available, as of 2018, nearly half of all published materials being used in classrooms were published before 2009 (Smith, 2020). Therefore, out-of -date curriculum may impact teacher implementation and the feedback provided by teachers may also be out of date.

Teachers must understand both content and structure of the NGSS, as well as how to adjust their teaching practice to meet these new standards (Reiser, 2013; Windschitl, Schwarz, & Passmore, 2014). With the release of the NGSS and its adoption, science educators are being asked to transform the way they think about the content by interpreting the standard and developing new ways to teach it. To implement the NGSS, teachers must reconsider how the science content is taught, how students build their understanding of that content, and how ideas fit together to tell a coherent story (Reiser, 2013). The resulting implementation of standards is an important aspect in understanding the framework of this study as it informs both the positives of standard implementation and the challenges. Furthering this, research has shown districts' choice of curriculum (which statistically would be out of date) reflecting standards varies greatly (Berland & Reiser, 2011; Herrenkohl & Cornelius, 2013) could impact the feedback provided by teachers after implementation and reflection. Therefore, the process of teacher interpretation, with its positive outcomes and its challenges in the standard implementation could be explored to gain a more holistic picture of why teachers are having challenges with the NGSS. As there have been several positive developments in the translation and enacting of the NGSS, there too have been some challenges.

Challenges of Teacher Translations

One challenge is lack of clarity, or coherence on what the standard or the related Performance Expectation (PE) is trying to accomplish, (Siebert-Evenstone, 2021), has been identified as a major challenge for teachers (Fulmer, Tanas, Weiss, 2017). Secondly, teachers struggle assimilating their personal beliefs with what a scientist can do and student capabilities (Achara, 2019; Bryan, 2003). Finally, teachers' personal feelings about the relevance of science content or their confidence teaching science can result in a failure to reflect the expectation set forth by the PE and, hence, their interpretation can result in a negative feedback of the translation of the standards (Reiser, Novak, Mcgill, 2017).

PE confusion

Existing curricula are not currently designed to support teachers' integration efforts; therefore, the lack of defined quality work of the standard many times impacts the feedback teachers provide because of their frustration with the standard (English, 2016). The vision of the *Framework* and the NGSS is for students to use scientific and engineering practices as a means for students to show evidence they are able to apply knowledge (NRC, 2016b). This effort is made more difficult by the nature of science being ill-defined historically, leading to various definitions of what scientific and engineering practices are and what they can look like in the classroom (Ring, Dare, Crotty, & Roehrig, 2017). This multitude of definitions lead to confusion as to what is important in science teaching, the content or the nature of science. Vague terms from the

PE, such as “deep understanding” or “strong” has led to challenges for teachers to interpret what successful mastery of the standards look like (Pruitt, 2014). The lack of agreement on the PE terminology could be an inadvertent quality of the subject matter. For example, LaDue, Libarkin, and Thomas (2015) argue that the SEPs are used differently across science disciplines (e.g. earth to life science), which can afford different opportunities for integration and implementation. For example, Appendix F lists the SEPs, and one practice is developing and using models. The models developed exploring global climate change in a biology class may be one of plant phenology, while in chemistry class, the molecular build-up of carbon dioxide may be utilized. This unequal representation, while both correct, can lead to confusion over how to develop and use models.

The standards and the PE are targets for the end of a particular grade or level, could be revisited at different times in a lesson sequence, and do not serve as a basis for a standalone unit. So, this bundling, and parsing, of standards and their PEs leads to teacher frustration as clear lesson sequences are not defined (Krajcik et al., 2014). Attempting to plan out these lesson sequences or units continue to frustrate teachers as the PE sequence has no coherent flow leading to challenging interpretations and can result in negative feedback (Nordine et al., 2017).

Conceptualization not representative of intent of standard

Not only is standard translation challenging to accomplish, but Ring et al., (2017) also found that practicing science teachers conceptualized standards in various ways and that these conceptions change over time as teachers interpret standards into curriculum. Conceptualization could be as unique as the teacher themselves, with each teacher bringing their outside experience with science and content knowledge to the classroom. As content knowledge deepens, or outside experience changes, so does teachers' conceptualization of the nature of science (Ring et al., 2017). These changing conceptions have led teachers to not be comfortable with adapting their pedagogy to any new standards as it fails to meld with their personal beliefs (Wilde, 2018). Also of note, science teachers lack an understanding of the nature of engineering, limiting their ability to effectively interpret standards for science instruction (Cunningham & Carlsen, 2014). The PE itself is meant to be a translation of the standard; teachers are often seen adapting the PE of the standard back to one more in line with their own conceptions which are novice understandings of engineering (Ring et al., 2017). The changing conceptualization, failure to adapt pedagogy, and novice understanding of engineering can create more frustration in teachers. This level of frustration can manifest as negative feedback about the standard to those responsible for altering or deleting standards.

The adaptation may also occur due to lack of assistance from tools designed to unpack the NGSS standards. The EQuIP rubric, for example, has been a tool teachers have used to interpret their lessons is not without faults (Neidorf et al., 2016). The Rubric has undergone multiple iterations since its publication, has accompanying videos for implementation, and supports the implementation of professional development, all of which increase the challenge of teachers conceptualizing the intent of the standard (Duncan, Chin, Barzalai, 2018). Another major fault is the EQuIP rubric fails to provide recommendations for the scale of PE execution (Neidorf et al., 2016), and detailed definitions of what adequate evidence would entail (Alonzo, 2013). Using or misusing this particular tool can also add to teacher frustration and result in negative feedback regarding their experience with the NGSS.

Faulty Assumptions

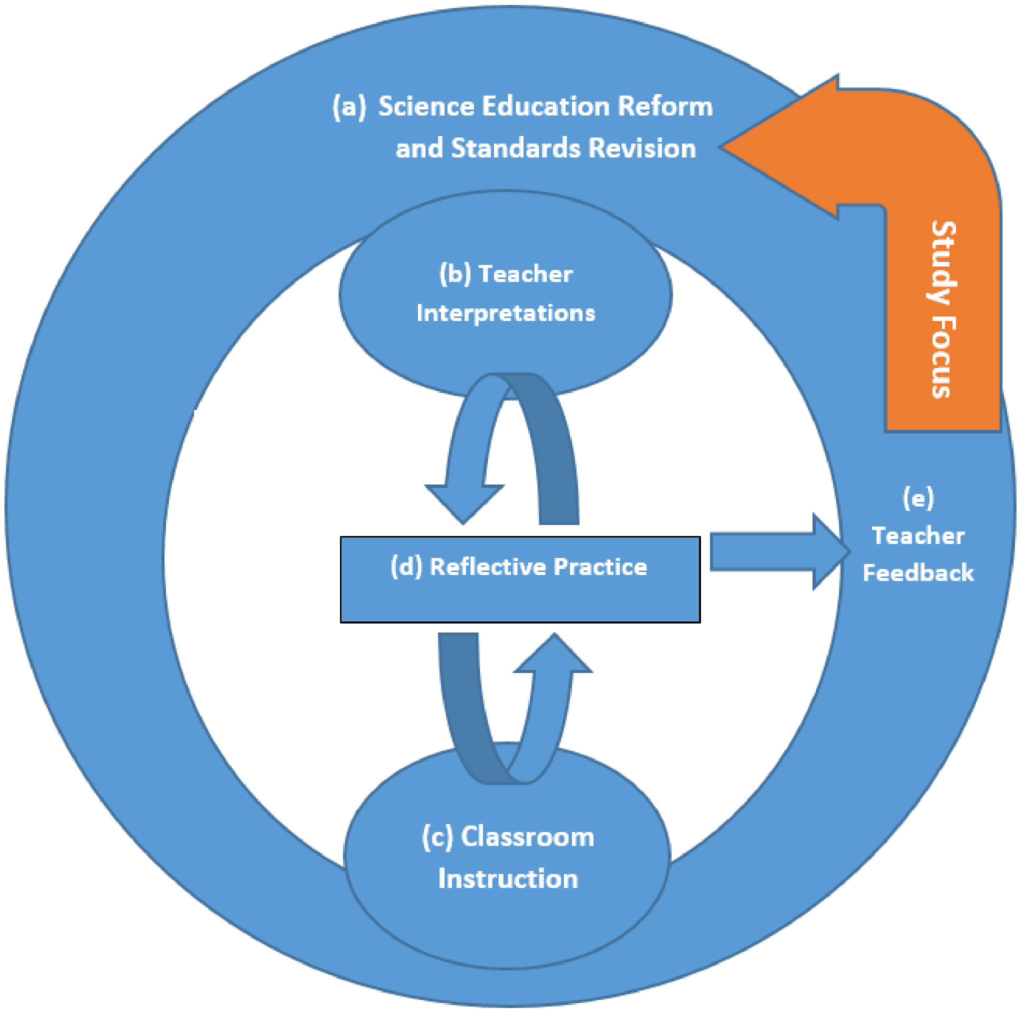
Teachers often have translated the standards not based upon their beliefs but on the perceived abilities of their students (Cess-Newsome, 2007). This interpretation in many cases has led to PEs not being reflective of the standard translation (Perry & Lawrence, 2017). Oftentimes when teachers do not believe in their students' abilities, the standard translated reflects this lower expectation, which can often be the case for historically disenfranchised students in science (Weiner, 2016). Teachers who believe they are drawing on local funds of student knowledge may not have an accurate representation of their students. In many cases this misrepresentation leads teachers to utilize specific classroom opportunities, such as experiments or data collection as opposed to experiment design and limitations of models (which are SEPs), which teachers believe their students are capable of (Perry & Lawrence, 2017). This lack of belief in ability brings about problems for implementing the NGSS in a respectful and equitable way (Licona, 2013; Seiler, 2013). Not only are the classroom opportunities given by the teacher to the students based on perceived expectations, certain standards are prioritized in the curriculum by teachers that they believe are easier (Licona, 2013). Low expectations such as these often lead to low achievement in science, and the result may be misplaced negative feedback toward the standards being too challenging.

The challenges presented with translating an all-encompassing set of science standards has been difficult for teachers to accomplish. Confusion over the PEs, evolving conceptualization of the nature of science, and an ever-changing population of students has highlighted the difficulties of implementing science standards to achieve the intent of the standard.

Conceptual Framework

Figure 1 is presented below. To begin, the study's framing is aligned within the (a) science education reforms and revision, which were driven by public opinion responding to international events such as the drop in United States scores exhibited on the Program for International Student Assessment testing. Once the standards are developed, teachers must next (b) interpret the nature of the reform and then translate the standards into both curriculum and instruction within their respective classrooms; a process that exhibits both challenges and positives of implementation. The interpretation process represents an important aspect of the model as teachers may struggle to make relevant the science standards and how they apply to their classroom (Ricketts, 2014). Next, (c) classroom instruction occurs as teachers translate the standards into classroom practice. From here, (d) reflective practice can occur as teachers reimagine their instructional approaches and determine the outcomes of the new lesson. Finally, after enough iterations of lessons, teachers can provide (e) feedback to policy and curriculum makers on the challenges within classroom instruction based on their experiences in hopes to influence (f) the next set of standards as they did with the NGSS. The focus of this study pertains to the feedback provided by teachers, as stakeholders, who are aiming to influence potential standards revisions given their expertise implementing the standards in actual classrooms.

Figure 1. Conceptual Framework



Original conceptual framework illustrating science standard reform via teacher feedback (Trzaskus, 2022).

Summary

Within this chapter I grounded the reader in understanding the process of science standard reform. In that framework I also provide details as to where teacher translation and teacher feedback are present. I discussed teacher translation as an important variable in the framework but is not the focus of this study, and therefore was only acknowledged. The following chapter sets the framework to analyze teacher feedback via public comment, which is what this study seeks to understand as it may drive changes in science education reform.

CHAPTER III

METHODOLOGY

In this chapter, I describe and justify the study's research design. I also detail the study's assumptions, limitations, and ethical assurances. The current study represents an analysis of responses from participants who responded to a public survey administered by the Kentucky Department of Education (KDE). The following research questions guided the study:

1. What comments are conveyed via public survey by teachers regarding the implementation of the Next Generation Science Standards?
2. What suggestions for improvement were given by teachers to alleviate the challenges they have seen regarding implementation?

Research Context

Standards Review

In 1990, the Kentucky legislature began creating a process for reviewing all academic standards and aligned assessments. The process was expanded and amended through July of 2020, which aligns with the comments from this survey. The legislation's purpose was to "give all Kentuckians an opportunity to participate . . . and shall ensure the public's assistance in reviewing and suggesting changes to the standards. . ." (KRS 158.6453, sec. g;par. 1, 2020). In order to define what the public would be commenting on and limited to the Kentucky Department of Education stated the feedback would be on standards only:

> Standards outline what students are expected to learn in each grade to successfully transition to the next level of learning. The curriculum or methods and resources used to teach the standards is a separate issue, and decided at the local level (KRS158.6453, sec. a, 2020).

In response to this call for feedback, a survey was created and advertised on January 22, 2021 and remained open until February 22, 2021. Participants were provided with the opportunity to give feedback on all standards or self-selected areas of interest. All survey responses were collected by The Region 5 Comprehensive Center.

The Region 5 Comprehensive Center has a mission to build the capacity of the state education agencies of Kentucky, Tennessee, Virginia, and West Virginia. Within the state of Kentucky, the Center had three objectives, the accelerated learning framework, economic shutdown impacts, and updating the state's science standards to better align with current research and reflect stakeholder feedback. The Center collected all data from the survey, provided descriptive statistics of participants, organized it by standard, and created four categories:

1. Negative Comments—Critiques without suggestions for improvement
2. Suggestions for Improvements—Comments that include constructive feedback
3. Positive Comments—Statements in support of performance expectations as written

4. Other Comments—Additional information that is not covered in the aforementioned categories

Figure 2 below, represents a screen capture of the survey results which include how the Region 5 Center categorized the participant responses. Screen captures of the document are provided as the electronic copy obtained was a PDF file. The categories of the responses, however, were not used through the course of this study's analysis, instead applying a grounded theoretical approach to extract emergent categories.

Figure 2. Example of sorted data from Region 5

KAS for Science: Draft Results and Summary

Middle School Earth/Space Science – Earth's Systems

06-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

Negative Comments

» This is really for all of the standards and not just this particular one. There is way to much depth to these standards to be taught effectively. They overwhelm new teachers. This is especially true for those of us who have to teach several grade levels through the day, it is nearly impossible to prep for such lessons when you have 5+ preps per day. I have set through dozens of trainings on these NGSS standards and no one has a firm grip on them. I have been told well to fully understand you must reference "appendix...." It should not require a teacher to reference three books in addition to their standards to build a quality lesson. These need to be re-done from the ground up.*

» Too broad

Suggestions for Improvement

» water cycle and nitrogen cycle maybe address the carbon cycle

» Develop a model and describe the cycling of Earth's materials and the flow of energy that drives this process. Decide what the goal will be or allow for multiple forms of assessment to demonstrate the goal.

» In the DCI associated with ESS2-1 references energy flow and matter cycling in living organisms however the PE, clarification statement and evidence statement don't reference that piece of the DCI. Consider removing?

» More specific on which cycles and what types of models.

Positive Feedback

No comment.

Other Comments

» See 06-ESS1-1 (Refers to this previous comment: I think that the content in appropriate for 6th grade, but I think that standards (in general) need to be broken down with a more obvious

Participants

Participation in this survey was open to any person in the state of Kentucky. In order to court the stakeholders that would most likely respond, KDE posted the survey on their website, as well as linking it to their electronic publication *Kentucky Teacher*. The communication is sent to Kentucky educators of all disciplines using the KDE's public delivery system which houses approximately 40,000 email addresses of teachers. In addition to this platform, other methods of participant courting were done by public announcement in education newsletters and encouraged teacher to teacher sharing. The report notes teacher to teacher sharing was the most popular distribution method as over half received the survey link from a colleague.

A total of 553 participants completed the survey. Not all who completed the survey commented on all the standards. More than half had no suggested changes to any portion of the NGSS. Of the 553 participants, 348 had no proposed changes or comments at all. The remaining sample size is the 205 participants who commented on the standards. Among those participants who provided comments, they did so on average for a little over five performance expectations. Teachers comprised 448 participants of the total 553. It is not noted how many of the 205 participants who commented were teachers. The low response rate, (553 of a potential 40,000) should not be misconstrued as acceptance of NGSS and its implementation. Nor should the overwhelming ratio of negative to positive comments be misunderstood as a referendum against the NGSS as negative comments from a public survey are far more common (Pikkareinen, 2021). This context, was utilized in the interpretation of the data set.

The high participant drop-out rate is not uncommon for surveys with open-ended questions (Andrews, Nonnecke, & Preece, 2003; Behrend et al., 2011; & Décieux et al., 2015). There are several possibilities for why many participants dropped out, but most often cited is the length of the survey (Hoerger, 2010). The question order of the survey included demographic information questions first, and then asked for opinion on all science standards the participant wished to comment on. Many times, participants who see multiple open-ended responses do not take the time to respond if there is no tangible reward (Nestler et al., 2015). In other circumstances attrition and personality of the participant cause them to end without responding (Hochheimer et al., 2016). However, the assumption in which drop out participants had some level of satisfaction with the NGSS should not be made. If a participant made any comment, even a "No comment" or "N/a," the Region 5 Comprehensive Center noted those comments. Furthermore, participants were asked for their opinions on the standards both positive and negative. Therefore, acceptance of the NGSS as is should not be implied by a participant who dropped out of the survey.

As the overwhelming majority of participants were teachers, descriptive statistics of all respondents (see Figures 3 & 4) serves as a useful estimate of the teacher sample, and for clarity of writing the participants providing the data for this study will be referred to as "teachers" even though a small percentage of them did not explicitly identify themselves in that role.

Figure 3. Grade level representation of participant teachers

What grade levels(s) do you represent? (check all that apply)	Responses	
	Percent	Number
Pre-K	0.00%	0
K	6.07%	27
1	6.07%	27
2	7.19%	32
3	6.29%	28
4	16.40%	73
5	7.64%	34
6	16.63%	74
7	22.47%	100
8	19.78%	88
9	22.25%	99
10	26.97%	120
11	28.31%	126
12	23.82%	106
	ANSWERED	445

Figure 4. Years of teaching experience of participants

How many years of teaching experience do you have?	Responses	
	Percent	Number
0 – 5	21.62%	96
6 – 10	23.87%	106
11 – 15	19.37%	86
16 – 20	17.57%	78
21 – 25	10.59%	47
26 – 30	4.95%	22
More than 30	2.03%	9
	ANSWERED	444

Most teachers identified as working in a secondary school setting, 9th-12th grades with the second largest concentration at the middle school levels (grades 6-8), with 11th grade, and in middle school 7th grade, being the most frequently selected response of students taught;

this is likely due to the fact that in Kentucky grades 7 and 11 are when the state standardized test in science is administered. Almost half of the teacher participants had ten years of teaching experience or less with 6-10 years being the most selected response.

Primary Data

As mentioned previously, 1,037 comments were provided regarding the NGSS that were broken into categories by the Region 5 Center prior to public release. A summary of this breakdown is found on Table 1. High school life science had the most total comments at 177, and Kindergarten had the fewest.

Table 1

Comments made on PEs by grade and category as assigned by the Region 5 Center

GRADE	NEGATIVE	SUGGESTION	POSITIVE	OTHER	TOTAL
K	3	8	0	2	13
1	0	4	0	10	14
2	16	4	0	1	21
3	1	7	0	6	14
4	18	80	0	17	115
5	8	6	0	14	28
MSPS	38	69	0	42	149
MSLS	33	75	0	7	115
MSES	28	33	1	16	78
HSPS	35	54	1	17	107
HSLS	24	111	2	40	177
HSES	8	27	0	10	45

**MSPS–Middle School Physical Science; MSLS–Middle School Life Science; MSES Middle School Earth Science; HSPS–High School Physical Science; HSLS–High School Life Science; HSES–High School Earth Science*

Figure 5 below, is a screen capture of the comments for 08-LS4-1 to aid the reader in understanding the variety of the comments, their length and their content.

Figure 5. Comments from 08-LS4-1

08-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

Negative Comments

» This is really for all of the standards and not just this particular one. There is way to much depth to these standards to be taught effectively. They overwhelm new teachers. This is especially true for those of us who have to teach several grade levels through the day, it is nearly impossible to prep for such lessons when you have 5+ preps per day. I have set through dozens of trainings on these NGSS standards and no one has a firm grip on them. I have been told well to fully understand you must reference "appendix...." It should not require a teacher to reference three books in addition to their standards to build a quality lesson. These need to be re-done from the ground up.*

Suggestions for Improvement

No comment.

Positive Feedback

No comment.

Other Comments

» Lots of suggestions in all standards if I get a chance to talk or communicate with someone rather than filling the survey. Thanks

Within the responses collected, feedback was also solicited regarding the Engineering and Technology Standards. In brief, respondents were asked to vote whether the Engineering and Technology Standards should be (1) embedded into the Kentucky Academic Standards, (2) be incorporated as a stand-alone standard, (3) mixed in some way, or (4) other suggestions. This prompt yielded 161 comments, none of which were attributed to teachers. 84 responses signaled these standards should be embedded, 12 stated stand alone, 10 mixed, and 55 had other suggestions. Due to the purpose of the data source, these votes were not utilized within the current study.

Data Sourcing & Analysis

Data Sourcing

Although the categories were predetermined by Region 5 Center, this classification of comments was not continued within the study's forthcoming analysis. The methods used by the Region 5 Center were not relayed in their report and validity could not be determined, and so this study began with the unedited comments as its source data. Once the report was complete, I requested the document through KDE open records request and received the document within 72 hours. The document contained all demographics of participants, quantification of comments on the Region 5 Center's classification, word clouds of frequently occurring words in comments on standards, and the comments verbatim attached to the standards. These verbatim comments were taken and analyzed according to the following methodology.

Data analysis

The primary data, which were the verbatim comments, were coded in a three-step process. The first cycle illustrates how descriptive codes were created from the primary data. Second, descriptive codes were sifted, and rebuilt around several central themes via a method of axial coding. Once all codes were included in grouping of like themes, or excluded, then the third round of coding from those themes took place. In the third round of coding, focused coding, the central themes were analyzed, compared, and focused in order to create connections among the axial codes. Finally, hypotheses were generated based on thematic categories in order to answer the study's research questions. This process was completed utilizing constructed grounded theory (Charmaz, 2006).

Constructed Grounded Theory

Constructed grounded theory allows this study to focus on reducing the data into manageable segments through the application of inductive codes. This reorganization of data allows for the verification of data-driven conclusions (Charmaz, 2006; Miles & Huberman, 1994). The study's primary source of data (i.e. survey comments) varied in length and complexity. Interpretation of the meaning of the data is appropriate in this methodological approach. Constructed grounded theory provides the researcher ways to systematically describe the data for constructing meaning (Goldman, Graesser & van den Broek, 1999), and can be applied to any form of data where in a researcher seeks to generate meaning from the data (Früh, 2007; Groeben & Rustemeyer, 1994; Holsti, 1969; Krippendorff, 2004; Mayring, 2000; 2010; Shapiro & Markoff, 1997).

The grounded theory methodology consists of a three-step coding process in data analysis. The first step is descriptive coding, where the data will be analyzed for noteworthy statements and significant themes related to how stakeholders perceive their utilization of the NGSS. The descriptive coding remains closely related to the verbatim data in order to remain open to the ideas that emerge (Glaser, 1978). For example, if the primary data is *"Not significant to daily life of non college bound science"* the resulting code would be "lack of significance/relevance." During this cycle of coding I reuse words or phrases from participants allowing for the emergence of thematic codes which may answer one or both of the research questions. For ease of analysis, data is next categorized into repeated ideas and grouped into a chart or cluster of axial codes (Brand & Wallace, 2012). This categorization reflects the "constant comparative method" (Glaser & Strauss, 1967) to make analytic distinctions in the data.

There is a potential data could yield multiple codes due to the complexity and multiple ideas expressed by stakeholders within their comments. Regardless of emergence, clustered descriptive codes would be compared to identify potential broader themes during the second cycle. The complex nature of the data leads to making inferences beyond verbatim words provided. Due to this, descriptive coding is more appropriate in short phrases rather than singular nouns (Berger, 2014). Coding in phrases allows for a deeper analysis of primary data beyond the first cycle of coding (Saldana, 2016).

Overview of the Three Step Process of Constructed Grounded Theory

All data is first uploaded to a qualitative data management software program for organization and analysis (NVivo, 2014). The inductive analysis strategies of constructed grounded theory (Charmaz, 2006) guides all phases of analysis. Constructed grounded theory is an appropriate strategy as data become named via newly created codes. Knowledge of what these codes are constructed by the data, coding frame, and focus of the research question. These descriptive codes are generated and clustered as axial codes (Charmaz, 2006) which are used to consolidate the initial descriptive codes into broader, inter-related focused codes, in the later steps of the coding process (Fielding & Fielding, 1986). The final phase of analysis involves the testing of inductively generated focused codes that give assertions for "evidentiary warrant," which is an assertion, not proof, to persuade the audience the generalizations made by the researcher about the data are reasonable (Erickson, 1986)..

First cycle descriptive coding is spontaneous, keeping in mind that codes can be tentative and change their meaning through further rounds of analysis. The speed of the coding allows me to utilize my coding frame and subjectivity in a natural way. Once a spontaneous descriptive code is created, it is not revisited or altered during the first cycle. This process creates several codes that may be very similar in their meaning and are sifted or combined during later phases of coding. Furthermore, descriptive coding of the primary data is utilized due to the length and nuanced levels that may be seen in the primary data upon initial analysis. Descriptive coding allows more flexibility than line by line or paragraph coding (Miles, Huberman, & Saldana, 2014).

Analytic memos were periodically made throughout the first cycle coding process. The memos allowed the researcher to capture pieces of data verbatim that exemplified the descriptive code given, thoughts relevant to further analysis of data, portions of the conceptual framework which were highlighted by the code, or possibility of occupation of the participant. Also, memos were utilized to capture researcher reflections, questions about the data, and other thoughts or musings concerning the data. Most of the content written in the analytic memos was not displayed within the findings, but instead utilized to further inform the research and keep the researcher focused on the framework and research questions during analysis. An example of a researcher creating an analytic memo can be found in Appendix A.

For example, the following descriptive codes were clustered within a broader inter-related category: "lack of significance/relevance; culturally bias/inappropriate; students lack understanding; unable to accomplish," would all be paired together and given an active verb phrase of *"lacking preparation to teach,"* during the second step.

The second step was axial coding in which patterns are identified. In this part of the process, the most frequent or most significant codes are used in order to sift through the large amount of resulting data (Charmaz, 2006). The goal of this cycle was to create a central skeleton which unites the descriptive codes. The sifting was completed once axial categories are created through comparing codes to codes and all descriptive codes have been included or excluded (Hoonaard, 1997).

Lastly, focused coding was used to narrow the responses into core categories that have a similar theme which were considered to be evidentiary themes. These themes can be overarching and represent the central thesis of this research, and was the core idea behind the emerging theory (Charmaz, 1991a). The theme can be an existing category that was derived earlier, or it may be a new category derived from the previous cycles of coding (Charmaz, 2006). For the purposes of this study, axial codes such as "lacking preparation to teach; lacking resources; lacking specificity," could be made into an evidentiary statement of *"teacher preparation and personal experience is lacking"*. The conclusion of this step is the verbalization of the theory answering the research questions of what messages do Kentucky science teachers wish to convey to policymakers.

Cycle 1 coding—descriptive codes

The study's primary data source consists of a compilation of comments given to the KDE in response to a survey taken by various stakeholders. In total, there were 1,037 collected comments which were sorted across the categories. Out of those comments, 744 were unique comments which did not repeat across multiple standards. These comments were represented in the first cycle of coding data creating 744 new codes. From these 744 new descriptive codes, many were repeated, and a total of 194 unique descriptive codes were created for the second cycle analysis. A full display of all descriptive codes is located in Appendix B.

Descriptive Coding Process

The descriptive coding process of this study led to a categorized inventory of the primary data's contents which allowed for an organizational grasp on the study (Saldana, 2016). Table 2 below illustrates the creation of descriptive codes from primary data. The table shows the descriptive code, and the selection of primary data that informed the descriptive code.

Table 2

Examples of primary data which gave rise to descriptive code

Descriptive Code	Stakeholder Comment (excerpts)
Difficult to assess	*How does one measure "ask questions"?* *Difficult standard to test and assess.* *Difficult to assess.* *Difficult to realistically graph and assess.*
Tier the standard	*This needs to be tiered. Students at different levels would expect to understand this differently.* *Needs to be tiered. Students are not at the same levels mathematically.* *Tier it. The mathematical relationships here are extremely complex.* *This needs to be tiered.* *This should be tiered.*
Focus is too specific	*It sounds like someone wrote it with a specific project/task in mind and that should not be the focus of our standards.* *Too specific for general physical science.* *This is a very specific standard.* *Could be combined to form a broader topic or standard that you are reaching for.* *This is too narrow of a focus.*
Not significant or relevant	*Not significant to daily life of non college bound science.* *This should not be a science period.* *Ideally not all high school students need this standard in order to be successful in the field.* *Why is this included in any standards beyond those for geologists?*
Too abstract for students	*This is too abstract for most 6th graders.* *Very abstract thinking is needed to apply these ideas.* *Some students are able to understand the abstract ideas here while many are stuck in the concrete level.* *Abstract thinking eludes many students regarding this phenomena.* *This also needs to be less theoretical.*

Cycle 2 coding—Axial coding

Introduction

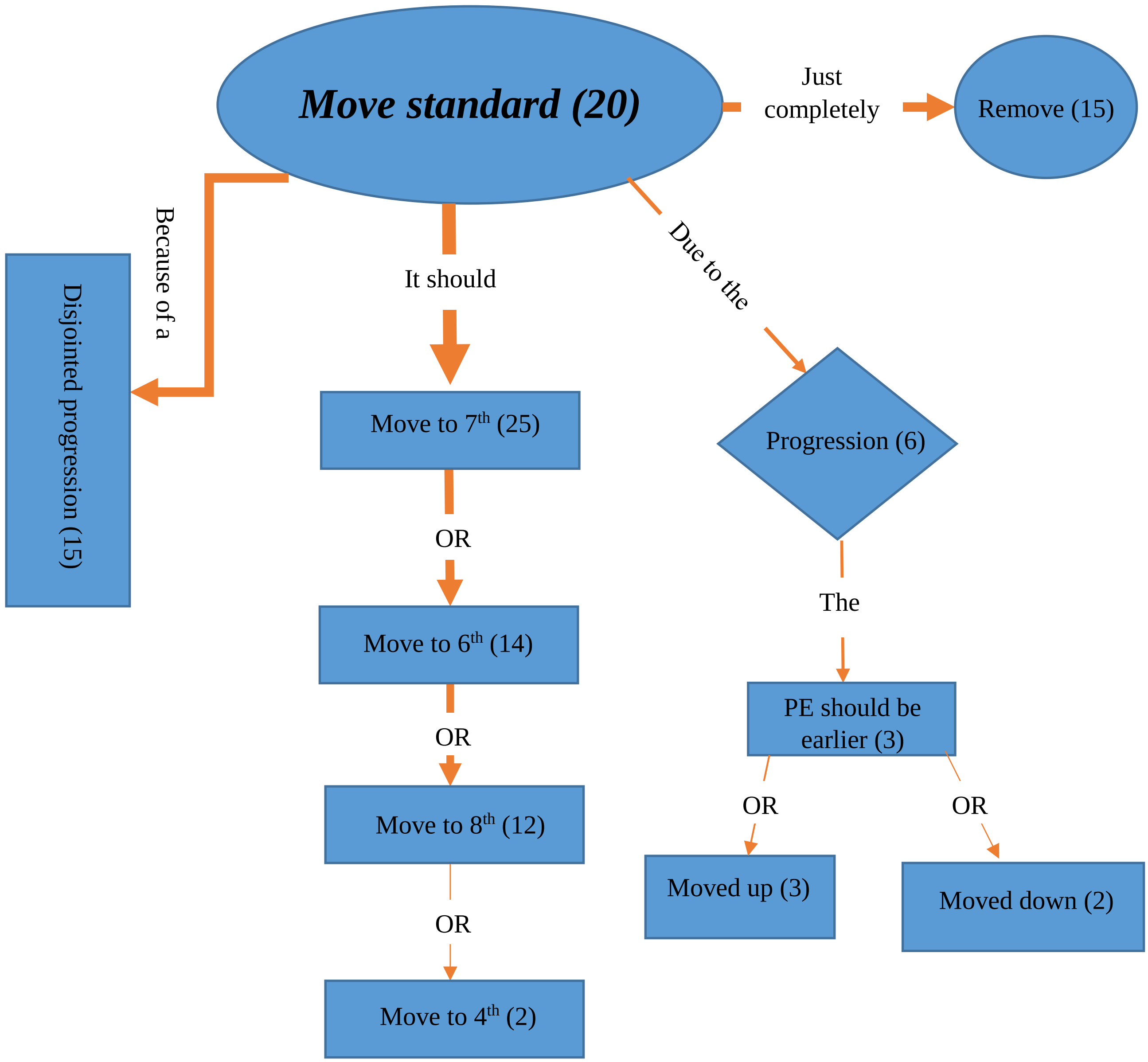
During the second cycle of coding, the inventory of descriptive codes were placed in categories or themes that were "split" or "fractured" during the first cycle process (Strauss & Corbin, 1998, pg. 124). This was done to determine which of the 194 descriptive codes were the most dominant, organize synonyms, and remove redundancy to display the most representative codes (Boeije, 2010).

Axial coding process

The process of placing the descriptive codes into categories happened quickly, but I remained open to naming the axial code until all codes were sifted once. In order to pursue this process effectively, Miles, Huberman, and Saldana, (2014) suggest chunking codes loosely with each other so codes can be rearranged as needed. Following this recommendation, all first cycle codes were combined to show the previously mentioned 194 unique descriptive codes. Next, these codes were printed onto paper, cut out individually, and placed on a large surface to be physically manipulated and categorized. A photo of this process can be seen in Appendix C.

As this process unfolded, categories emerged and relationships were shown through like properties. The dimension of the properties and their level of importance were checked against the code count of Appendix A in order to ensure the most representative codes remained. To illustrate the nuance within the axial codes, short phrases were placed between the axial code and the descriptive code in order to see the connection clearly between the codes. An example of the process is illustrated below on Figure 6.

Figure 6. Sample Axial Coding display with descriptive codes



The axial code can be found at the top of the figure, along with the number of times it was coded as a descriptive code in parentheses. Modifiers to the code are displayed below showing how each component relates to the new axial code. The arrows are weighted differently based upon how many times the modifier code occurred in the first cycle, and those numbers are located next to the modifier code in parentheses. The result of this process was the creation of fifteen axial codes with at minimum two distinct modifiers. A list of all axial codes and their connecting descriptive code modifiers can be found in a table in Appendix D.

Several codes appeared to have their own distinct meaning and could not be related back to a central theme. Prior to sifting these codes out, I compared these unique descriptive codes to each of the newly established axial codes for possible insertion. When this process did not yield results, the primary data of the code was examined. If there were potential connections, the code being referred to in an analytic memo, or connection to other distinct codes they were grouped on their own axis. If none of the conditions listed above existed, then the code was removed from further analysis. A total of twenty-seven descriptive codes were sifted out during this cycle, leaving 167 unique descriptive codes, supported by 703 stakeholder comments, categorized into 13 axial codes. A list of the 13 axial codes can be found below in Table 3.

Table 3

Axial codes with associated descriptive codes and supporting primary data

Axial Code	# of Descriptive Codes	# of Primary Data
Complexity	28	113
Students	27	57
Move standard	18	115
Relevance	14	28
Locality	14	23
Clarity	14	163
Resources	12	42
Teachers	11	30
Knowledge	9	47
Addition	8	41
Wordy	5	21
Assessment	4	11
Redundancy	3	12
TOTAL	167	703

Cycle 3—Focused coding

Introduction

During the final phase of coding, axial codes were synthesized to represent large chunks of data. Through the process of focused coding, I created codes that gave rise to potential answers to the study's research questions with the overall goal being to determine the adequacy of the codes I created from previous cycles. By taking this approach, I was able to determine the participants' meanings from their answers given by the survey prompt.

Focused coding process

In this cycle of coding the research questions were utilized to guide the final coding cycle. The content of the descriptive and axial codes were analyzed to determine answers to one or both research questions. First, the axial codes were analyzed, synthesized, and grouped into a broader theme. Then, the axial codes were lumped together by how they answered the research question. Next, a priori of evidence was created using each axial code to determine if the focused code narratively answers the research question succinctly and completely. In some cases, axial codes leant themselves to answering both of the research questions. In those cases, Dey, (2007) suggests that connections be made by categorizing data, and admitting that there may not be clearly defined boundaries. When there are no clear boundaries, I determined the degrees of belonging the codes have in each category and described those relationships along with the strength of the relationship (Dey, 2007). By allowing the analysis of the focus codes to be flexible, I limited preconceived notions of the data and increased the trustworthiness of the study. All of the decisions made regarding coding were based upon my coding frame.

Coding Frame

The researcher utilizes the study's frame during analysis as an exploratory approach to the data with the goal of illuminating stakeholder, presumably teacher feedback, concerning the NGSS. The study's analysis was to better understand the challenges seen by stakeholders which could include, (a) the willingness to implement the NGSS; (b) their [teacher] experiences or preparedness for such a task; (c) their [teacher] knowledge of or relevance to the standards. (It was assumed that teachers are the participants who have the most knowledge as to the effectiveness of implementation. This is discussed as a limitation of this study later). Throughout this form of analysis, constructed grounded theory positions the researcher to utilize the coding frame while reflecting on the study's research questions, through their own relevant subjectivity, and themes emerging from the data (Schrier, 2006). The researcher uses active verbs throughout analysis, particularly when the data set is associated with potential change or areas of improvement as the data are relevant for study (Finelli, Daly, & Richardson, 2014). Given the types of complex extensive data, data reduction is used to hone the focus of what data will be more valuable than other data based on the focus of the research question (Groeben & Rustemeyer, 1994).

Researcher Subjectivity

Codes are subjective, and will reflect the researcher's experiences, knowledge, and interpretation of the data presented (Atkinson, 1996). Although coding is subjective, it comes from a place of authority as I (the researcher) have similar experiences as the participants. To increase the trustworthiness of the coding frame I will address my subjectivity now. The researcher is the individual creating the codes from the statements created from the survey in order to find the main theme or themes that Kentucky science educators wish to convey. I am an appropriate vehicle for this methodology as my personal experiences match the most common participant (Kentucky science educator) of the study to analytically infer the themes that may be extracted from the descriptive initial codes. I am a Kentucky science educator with his own opinions regarding the NGSS, their effectiveness, and their worthiness to students. I have worked for 6-10 years in the teaching profession which mirrors the majority of the participants. Next, during that time span, I have been asked to teach all of the NGSS science standards in high school, which is the level of standards commented on the most. Furthermore, my teaching career began as the NGSS began in the classroom, and as such I am personally aware of some of the successes and challenges of the roll out. Finally, I have made every effort to stay open to the themes in the data; however, personal experiences will affect the coding, analysis and themes created.

Assumptions, Trustworthiness, and Ethical Considerations

Several assumptions took place in regards to the study, mostly concerning the equitable collection of the data prior to analysis. It is assumed this research data obtained through open records are accurate, complete, and unaltered. It is also assumed participants gave legitimate responses regarding the PEs and had some interaction with the PEs as stakeholders. Another assumption is responses in the data were reflective of teachers as most participants identified as such. Finally, it is assumed that these comments were made in order to support, improve, or change Kentucky science standards. A separate assumption acknowledges the selection bias of those who participated in the research. The participation appears to be biased towards data that recognizes individuals who seek changes within the NGSS and not those who agree with the changes which the NGSS has implemented.

Trustworthiness

Transferability refers to the idea that the findings gathered from the data can be applied to other similar settings and context (Brand & Wallace, 2012; Korstjen & Moser, 2018; Mandal, 2018; Yin, 2012). Based upon the specific nature of the study, there may be a lack of transferability to other studies. The group of stakeholders are identified; however, comments in the data are not attributed to any one individual making it impossible to guarantee that they came from a teacher. Also, the dynamic nature of education leads to teachers coming and going quickly; therefore, the participants may no longer be a stakeholder in education or engage with the NGSS. However, the scope of transferability in any qualitative study is narrower, and is not intended to be fully transferable (Creswell, 2014).

Transferability

The transferability of this study is realized by the feedback and review of standards process. As Kentucky was one of the earliest adopters of the NGSS, educators in the state have had arguably the most experience with the standards. Teachers who work with the standards communicate their successes and challenges. These areas of growth and success may be present in other states that have not moved as far into the adoption process of the NGSS. This study can serve as a roadmap of potential pitfalls and points to emphasize as other states move through the adoption process.

Dependability

Dependability refers to whether the research findings are replicable and consistent (Korstjen & Moser, 2018; Mandal, 2018). Dependability for the study was achieved by providing in-depth descriptions of the study procedures, data analysis, and review of the entire study by a committee of field experts (Creswell, 2014; Donnelly & Trochim, 2008).

Ethical considerations

For this study, although individuals responded to the initial prompts and remained anonymous, since the survey used human participants, honoring privacy was a primary concern. To address this concern directly, the researcher obtained approval from the University of Louisville's Institutional Review Board (IRB). The Belmont Report, (Department of Health, Education, and Welfare, 1979), discusses tenets of respect of persons, beneficence, and justice, which were addressed in this study. Participant stakeholders volunteered their time and opinions willingly providing useful data for the survey. This reflects the tenet respect for persons.

The second tenet, beneficence, or do no harm, was displayed in the following ways. For this research, all participants volunteered for the survey. As all identities remain unknown to the researcher, no recourse, positive or negative can be had on the participants.

Finally, the tenet of justice was realized by the participant stakeholders as this report will be made available to researchers and other legislative bodies who influence curriculum and standards. If participants gave opinions which highlight deficits in the NGSS and ask for improvements, their comments would be directed appropriately to those that would have influence over changing standards, curriculum development, or material procurement.

SUMMARY

Chapter III presented the study's research design. The study will examine teacher feedback concerning the challenges of implementation of the NGSS as well as the suggestions for improvement. Data was obtained from this study by an open records request to the Kentucky Department of Education. KDE, in collaboration with Region 5 Comprehensive Center Network, made public the results of a survey including classifying the teachers' comments as negative, suggestions for improvement, positive, or other. Although these categories are provided, they were not considered in the analysis. An explanation of the data coding and thematic development processes for the research questions of this study was provided. The data analysis was conducted through the lens of emerging thematic data to answer the research questions. Limitations were addressed as well as assumptions about the data collection and participants. The chapter concluded with ethical concerns and protections for participants were explained to ensure the trustworthiness of the study. An in-depth analysis of the findings from this research study is provided in Chapter IV.

CHAPTER IV

FINDINGS

In this chapter I display the emergent themes from data analyzed by the methodology presented in Chapter III. These themes are organized by how they influence teacher implementation and teacher feedback. For implementation, teachers read the standard prior to designing instruction, and when there is disconnect for the teacher a challenge occurs. These challenges emerged in the focus codes of Chapter III and organized in Chapter IV to answer research question one. Teacher feedback occurs after lesson implementation. The themes of feedback teachers had after implementation also emerged as focus codes in Chapter III. These codes apply to research question two, teacher suggestions for improvement.

Research Question 1—Teacher feedback on challenges

The majority of feedback teachers gave about the NGSS highlighted challenges associated with classroom implementation. Teachers commented that the NGSS were not clear, too complex, and provided too high of expectations for both teachers and students. Within the three focused codes created, support was garnered for the codes from primary data and researcher subjectivities. The primary data through the researcher's subjectivity allowed for a synthesis of data and ultimately an answer to the research question. The answer is described in three sections, clarity of NGSS, teacher ability, and stakeholder expectations of students.

Clarity of the NGSS

The most pronounced categories that emerged dealt with the lack of clarity in the NGSS as espoused by teachers. Several comments revealed frustrations stemming from the wording of the standards, citing issues with verbiage and complexity of the language. Within the focused code of clarity, two related subcategories emerged, specificity and understanding, both relating to how clear the standards are to the teachers. The overall focused code of clarity represented 301 comments, 23 descriptive codes, and 6 axial codes. The number of comments within this category justifies it becoming a focused code. In terms of the subcategory specificity, excerpts of comments embedded within this subcategory of code are listed below:

> Very vague. / There needs to be more specificity here. / I wish there were more specifics for teachers to follow. / Wordy – be more specific about what is expected. / Be more specific with what you want.

The recurrent use of the word specific within the data illustrates the importance of this subcategory. It can be inferred from the adversarial style of comments that teachers ask for more examples or guidelines of what the authors of the NGSS believe are required for students to become scientifically literate citizens. By providing a clearer roadmap for teachers to follow, it is possible, the teachers believe students can be scientifically literate, but the NGSS in its current form is too challenging because it lacks specificity in its intent. For teachers the lack of specificity presents, in a nuanced manner, the feeling of hopelessness. Analyzing the exact words of the data, “I wish”; “. . . is expected”; “you want”, all present a level of conflict between presumably the teachers and the intent of the NGSS. These words reinforce the framing of this study. If the comments are from teachers, those making the comments have tried to implement the NGSS, but believe they have not achieved the intent of the NGSS. Presumably, the teachers are uncertain how specific they must be in their implementation. It can be inferred from the comments that after reflecting if they have accomplished the intent of the standard, teachers reflect and lament how well they have achieved the intent.

It is possible teachers presented their frustration with their understanding of the standards by providing comments such as this; “I even have a hard time understanding this as an adult.”; “It is unclear what this means.” “What does that even mean?”; “I have sat through dozens of trainings on these NGSS standards and no one has a firm grip on them”; “Present in 4th grade appropriate language.”; “This standard needs to be broken down into smaller chunks.” The comments shown here potentially illustrate the need for changes in the NGSS as the language is such that teachers do not understand. Participants voiced their concerns noting the expectations of understanding were too high for students. Participant's concern of the understanding, of students and teachers illustrates frustration just as the first subcategory illustrates. This feeling of frustration and possibly cynicism is best exemplified by the comment, “I have sat through dozens of trainings on these NGSS standards and no one has a firm grip on them.” This comment shows the frustration of many teachers as they share their lack of understanding of the intent of the standard. Furthermore, the comment is cynical, claiming no one is capable of understanding the intent of the standard.

The two subcategories of specific and understanding are closely related to the focused code of clarity. Within the subcategories, teachers show different levels of need ranging from a more specific roadmap, to voicing post-reflection frustrations of how to effectively implement the standard when there is a lack of understanding. In all cases, teachers believe the intent of the standard cannot be met with the clarity of the language of the NGSS.

Teacher ability

Teachers are the primary instrument for enacting the NGSS in the classroom. Oftentimes effective instruction is linked to student outcomes; however, teachers' ability to translate, reflect on, and then adjust instruction to meet the intent of the standards is important in student learning (Suppovitz, 2001). Regarding the NGSS, comments noted teachers did not have the ability to effectively implement the NGSS for multiple reasons. The focused code of teacher ability encompassed 53 excerpts, 14 descriptive codes, and 4 axial codes. Excerpts of comments leading to this focused code are listed below:

> I've been at this for 24 years and don't have this information in my head nor the ability to decipher exactly what is expected. / Many teachers don't know where to get the resources or how to supply the information to students to complete such a standard. / All science teachers I have discussed it with have different ideas and most just ignore it. / Our textbooks are weak in this area.

Inferring from this portion of the data the commenters were teachers as the most repeated descriptive codes were, (standards are) unclear to teachers; teachers need more instruction; and overwhelm new teachers. Each of the descriptive codes show an assumption. The descriptive codes impart beliefs in which teachers do not have the ability to execute the intent of the standard. These comments may exhibit reflection in practice. Within all of the 14 descriptive codes, no comments indicated possession, or the use of I, me, or we, in which teachers are taking ownership of understanding the intent of the standard. Inferring from this portion of data, there is disconnect between teachers' own perceived ability and colleagues' ability. Teachers assumed they were not capable of achieving the intent of the standard. There is a belief they lack either the capability or the resources to fully realize the intent of the standard. Several participants, presumably teachers or others familiar with school resources, noted the lack of available resources, whether it was a full curriculum, data for analysis, or specific examples as the main reason the NGSS was not doable in the classroom. Furthermore, the personal experience of the participant was based on the belief on how teachers utilized the NGSS.

Terms from the primary data included "overwhelm" and "frustrate" specifically referring to new teachers who have little to no classroom experience. These terms, which appeared in clarity as well, show emotions which may come from reflection after lesson implementation. Although these emotions may be from teacher participants, it is not possible to attribute the emotions to them. However, the strength of the emotion shows a level of intentionality where the teacher is trying to implement the standard to the best of their ability. Nonetheless, from the stakeholder comments, teacher ability to effectively implement the NGSS is lacking, and they believe there are several approaches to alleviate this issue such as more NGSS specific teacher training and adequate resources.

Stakeholder expectations of students

Student abilities are not measured by these data; however, stakeholder perceived expectations of the capability of students in understanding concepts as presented within the NGSS was provided. Expectations for students have often been related to student achievement; so, illustrating the stakeholder views of student ability becomes relevant (Contreras, 2011). In this study, the focus code of student expectations encompasses 107 stakeholder comments, 17 descriptive codes, and 3 axial codes. Excerpts of comments leading to this code are listed below:

> If I handed this to a student they would have no idea what this looks like. / . . . depth of this standard depends on math skills and may vary depending on which year in high school students take biology. / I do not see how this would apply to a 2nd grader. / This standard is very unrelatable to 6th graders [sic]. / too mathematically advanced to be understood by all learners. / It causes them to give up because too many pieces that are expected for them to put together.

Stakeholder perceived determination of relevance for students and the specificity of the content is another challenge of the NGSS. The espoused low opinion of student ability by teachers was exhibited by alleging student knowledge and relevance with the NGSS was lacking. One example is the descriptive code student background knowledge, which houses this comment, "I teach this at the freshman level and the standards which require students to plan and conduct their own investigations almost NEVER work." As the previous comment can be attributed to a teacher, they assume students do not have the ability to meet the intent of the standard, and students' lack of ability is a challenge to implementing NGSS.

Another example of teachers assuming students do not have the capability to understand the intent of the standard comes from the descriptive code, expectations are too high, which houses the comment, “It should be absolutely ridiculous by any reasonable person that this is a standard. Does the average U.S. adult citizen really need to understand stellar life cycles or spans?” This stakeholder comment acutely illustrates their feelings of the standard not being relevant to students, or to anyone, and what presumably teachers believe is necessary to be a scientifically literate citizen.   What teachers believe makes a scientifically literate citizen illustrates their wishes to change the content focus of science education.

Another comment about HS-PS1-7. *Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction,* was “Splitting this standard into one standard about the mole concept and another about stoichiometry is a much better representation of how understanding these ideas progress.” In this case the stakeholder is making an assumption potentially after lesson reflection in which students would better understand mathematical conversions if students could learn about mole relationships separate to stoichiometry.

Summary of results for research question one stakeholder feedback on challenges

Three focused codes emerged from the previous cycles of data analysis to answer the question, what feedback is conveyed via public comments by teachers regarding the implementation of the Next Generation Science Standards? It can be inferred that the codes show the participating teachers find the NGSS challenging to implement, and they have three reasons supporting the challenge. First, teachers believe there is a lack of clarity in the standard. The comments exhibited frustration in regards to the vagueness of the terminology, the science and math complexity, and the lack of specificity of success of the standard. Second, teachers believe they lack the ability to teach the intention of the standard. Several of the comments could be attributed to teachers directly based upon possessive terms used. Within these data there were calls for more resources, feelings of teachers being overwhelmed, and the assumption teachers do not have the ability to teach the standard. Finally, there is an assumption by teachers that students at any level are not capable of understanding the standards. They state the relevance or background knowledge necessary to meet the standard is not something which students possess.

Research Question 2--Suggestions for improvement to alleviate challenges

Probable teacher feedback regarding the implementation of the NGSS was negative and expressed a multitude of challenges inhibiting success of the standard. Although challenges were named, it can be inferred teachers also gave both general and concrete solutions to potentially improve the standards and presumably to improve student learning. Among some of the improvements given were access to resources, specific revisions of the standards, and the movement of standards in and out of grade bands in order to create a more uniform progression of the standards.

Need for resources

Requests for resources are not uncommon in educational settings (Sellmann, Beckmann, Panzlaff, Menzel, 2019). It can be inferred the feedback given was from teachers which outlined the issue at hand, and asked for specific resources that would be used to aid in teaching the NGSS. Some examples of comment excerpts which gave concrete solutions:

> Give us some data to teach these standards; / My school has the resources to do this both virtually and in person, but many schools do not and it is unfair to have so many standards tied directly to materials that students need to learn; / Many classrooms lack the ability to use computers

Based upon the comments, teachers would have reflected on their lesson and are searching for ways to alter their classroom practice to benefit students. Specifically the comment from 3-ESS3-1. *Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard*, "May not be practical in the elementary classroom due to limited freezer space availability." This comment illustrates a teacher wishing to do more within the classroom and is open to altering their instructional practice based upon resources available. Likewise a comment from 4-PS4-2. *Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen,* "Again there are not enough resources to have all students participate in this activity." This probable teacher, post reflection, understands the intent of the NGSS which is learning science through doing science. Their concern of lack of resources makes them feel as if this is not a task they can accomplish.

The hanging indented paragraph above represents excerpts from 57 comments, 11 descriptive codes, and 4 axial codes. To gain a transparent view of the coding frame being applied to the data, Table 4 shows the connection of the comments to the descriptive codes to form the axial code Resources. Beyond just asking for resources, stakeholders, presumably teachers, asked for specific tools to enhance or prepare for instruction, sources of data to support teaching the phenomena, assessments to help teachers identify student misconceptions and adjust instruction, and professional learning to help teachers translate the standard.

Table 4

Descriptive codes from the Axial code Resources with excerpts of comments and related standards

Descriptive Code	Excerpt of comments	NGSS Standard
FOSS curriculum not aligned	1. In years past the FOSS curriculum taught plant and animal structure and function. However, this year it was changed to only teach plant structure and function	1. 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction
No money for resources	1. We have no money to purchase model activities.	1. 06-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
	2. Cannot be done in classroom without a significant budget	2. HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
Support standard with resources and assessment	1. Have more support built in so teachers know how to teach and assess it	1. 07-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.
Teachers need tools/resources	1. This standard requires the construction, testing, and modification for a device not all schools can construct, test, and modify.	1. 07-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.
	2. Models to do this effectively are often too complex to	2. HS-ESS2-4. Use a model to describe how variations in the

Teachers need tools/resources (continued)	physically build in the high school classroom	flow of energy into and out of Earth systems result in changes in climate.
	3. Many classrooms lack the ability to use computers	3. HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
	4. I have no issue with creating a model to show energy flow, but a COMPUTATIONAL model to CALCULATE the change in energy	4. HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
Textbooks are not helpful	1. This is not even in our given textbook and I feel that the clarification statement goes beyond what should be expected in a general high school chemistry class	1. HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Other examples of possessives in the language illustrate that many teachers are looking for more specific instruction on how to implement the NGSS. Comments such as "There needs to be training offered in this (SEP) area," illustrate that likely teachers understand the content they are asked to teach, but cannot execute the application of the content. Another point asking for more instruction was exhibited by this comment taken from HS-LS1-2. *Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.* ". . .the arbitrary wording of the standard puts extra work on me the teacher." This point is echoed by seven descriptive codes seeking to clarify the language of the standard in some manner and those descriptive codes representing 87 comments. A sample of descriptive codes and comment excerpts with related standards can be found below on Table 5.

Table 5

Descriptive codes with comments to clarify language of the standard

Descriptive Code	Excerpt of comments	NGSS Standard
Clarify assessment boundaries	With SO many cells possible, there needs to be an assessment boundary as to which cells we should focus on	07-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.
Clarify intent of standard	STOP MAKING US DO EXTRA WORK BY DISSECTING THESE IN ORDER TO ASSUME THE INTENT	HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
Clarify with examples	I wish there were more specifics for us to follow	2-ESS1-1. Use information from several sources to provide evidence that Earth events can occur quickly or slowly.
Clarity	I need clarification	HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
Reword standard	This is not even in our given textbook and I feel that the clarification statement goes beyond what should be expected in a general high school chemistry class	HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
Reword verbs	Why does every standard need to be about models? Can't we just ask them to describe the cycle and assess that they understand it?	06-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

Verbiage Unclear	"Ask questions to clarify" doesn't support a solid depth and level of understanding.	HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Revising the wording of the standards

While being varied in their level of specificity, many teachers feel the NGSS should be written in a more understandable fashion. Some felt as if the standards should be written in student friendly language, others felt that SEPs should be simplified, and some questioned the ability of students to perform the standard at the written level. Although previously discussed in the specificity subcategory of the clarity focused code in research question 1, these comments represent specific feedback concerning verbs or phrases teachers believed needed altering. Feedback from this focused code represented 112 comments, 17 descriptive codes, and 4 axial codes. Examples include:

> "Obtain and combine" these verbs are not normal academic terms for 4th grade; / Teachers need more guidance here – WHAT design solutions? WHAT weather-related hazards?; / I guess I don't know if I am teaching the "pattern" part of the standard correctly; / Generate needs to be changed into a more student-friendly word; / Generate not a 4th grade academic term. Instead "create"; / So many verbs: Create or Revise to Test to Mitigate….Please simplify this; / Break down into multiple standards in smaller chunks

These data were more general in nature; however, specific suggestions including a complete rewriting of some standards were provided. Here is the original NGSS writing:

06-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Feedback from one participant asked the rewrite to be:

> Using Bloom's Taxonomy (not THESE necessarily, but something like this)- ESS1-1 Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. ESS1-1a- Define and describe rotation and revolution as related to objects' movement in space ESS1-1b- Predict lunar phases based on data provided (pictorial or numerical) ESS1-1c- Evaluate models of the Earth-sun-moon system that show patterns pf lunar phases, eclipses, or seasons ESS1-1d- Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Rewriting a standard in this manner personified many participants' suggestions for improving the standards through direct feedback.

Other suggestions included more minor revisions regarding the SEP or portions of the standards. Some of these suggestions included, "Competing design solutions needs to be more detailed;" "In my opinion natural resources should be discussed in another standard. Then organisms and populations of an ecosystem could be addressed in another;" "Remove humans from the standard;" The intent of the suggestions may be different as teachers are attempting to deal with multiple challenges in implementation; however, the overarching theme of rewriting the standards to be more understandable for students and teachers remains the same.

Move standard from current place in progression

It can be inferred from the language, teachers shared concerns regarding when standards were taught to students for several reasons. One concern was the lack of knowledge the student would have at the particular grade band. A second concern is the redundancy of standards or grouping like standards in the same grade band. The final concern involves placement of standards that are disjointed, or have no natural connection between standards or between content foci. This focused code represents 192 excerpts, 23 descriptive codes 5 axial codes. Some examples of these three concerns from stakeholder comments are:

> Move standard to 4th; / This concept should be taught in 6th grade; / Move to the 7th grade where students learn about thermal energy; / Reproduction and genetics is taught thoroughly in 8th grade also. Perhaps move this standard to grade 8 to ease the pressure of the 7th grade content; / There is only one standard in this area; / Should Newton's 1st and 2nd laws also be included in 6th grade standards to support this standard?; / This can be combined with HS-LS2-7

Degrees of specificity varied from moving and removing standards without justification to specific changes of standards to different levels in which teachers believe they are aiding in the education of students and reducing the challenges of implementing the NGSS.

The concern of standards being disjointed, in the teachers' feedback, affect both students and teachers. The disjointed standards for students inhibit a continuous content storyline, or make it more difficult to achieve the standard at a mastery level. Some comments which disrupt the content storyline are; “It does not really go along with other PS4 standards;” “This is the only one placed in the 8th grade and does not fit logically in the learning process;” “We are having a difficult time fitting into our Biology units.” States do choose the order of the curriculum; however, disjointed curriculum can lead to students not connecting with the content and lower achievement (Schmidt, Houang, & Cogan, 2002). This concern presented by teachers illustrates a lack of connection across contents for students and potentially a further challenge for teachers to implement the NGSS with fidelity.

According to teachers, not only is the sequence disjointed, but so is the students’ ability to achieve the SEP at the intended level in the grade band asked of the standard. Although these comments could be included with expectations of students, mentioned previously, the nuance of a suggestion to improve provided by the teachers pushed this feedback to a different category. Some examples are:

> Replace “mathematical representations" with “design process and collect data" which is a more appropriate way for students to demonstrate the standard. / I would like to see a different SEP for this one…more of using mathematics and computational thinking for students to predict the patterns/algorithyms (sic) etc. / Include evaluating claims, evidence, and reasoning. / Competing design solutions should be more detailed. / I feel like kids can analyze models but really struggle developing their own models.

These comments do not expect students to be able to achieve the SEP and give suggestions on how to improve upon this challenge coming from the elementary or middle school level. None of the comments included in this focused code included the grading of the students. Once again the reflective nature of the comments indicate teachers have asked the students to attempt the SEP and have not yet succeeded. Due to the teachers' lack of success with the SEP, they make suggestions on how to alter the SEP to a level they see fit for students. Based on the positive nature of the comments, teachers believe students can achieve these altered SEPs and these comments are not based solely on low student expectations.

Summary of feedback for research question two—suggestions for improvement

Participants, who presumably were teachers based on language used, provided very general and concrete answers to the second research question, what suggestions for improvement of the NGSS would alleviate the challenges of its implementation? These answers included asking for more resources from general funds, to physical space, from example data to updated textbooks and curriculum which would be used to support teaching and learning. A second suggestion participants provided was rewriting the standards to encompass more student-friendly language. Furthermore, participants felt as if the standards contained too much scientific jargon which created confusion for teachers on the intent of the standard. Not only did participants struggle with the wording of the standards, but they struggled with the sequence in which they were presented. Although much of the concern that the intent of the standard is too advanced came from the elementary and middle school grade bands, the participants did not focus on lacking student knowledge, but asked for the standard to be moved to a different grade to create a better progression of standards. Also, participants wished to alter SEPs for some of the same reasons, feeling as if the complexity of the SEP should be reduced or changed entirely in the elementary and middle school grade bands.

The suggestions, likely from teachers, asking to provide clarity to the NGSS through feedback aligns with this study's framework. The use of feedback shows the importance of reflecting on the instructional classroom practice and adjusting the content focus to meet the needs of teachers. Teacher abilities vary greatly and this may too be illustrated by the general and specific degrees of feedback provided by the teachers. Lack of clarity in the standard may be leaving teachers unable to fully implement the standard, which in turn, leads to more classroom challenges. Some of these challenges of teaching science effectively most certainly leads to lower student outcomes, and low outcomes reinforce teachers' low expectations of students.

Summary

In this chapter I detailed the results from coding the primary data. These data, which were comments potentially from teachers regarding the implementation of the NGSS, were individually coded descriptively. This descriptive coding allowed me to create or use words or phrases which were the most meaningful in line with implementation of, challenges of, or suggestions for the NGSS in alignment with the research questions. The first cycle yielded 194 descriptive codes. Justifications for these codes were presented and examples displayed in Table 2. Next, these descriptive codes were sifted or brought together into larger categories, and each category was given an axial code. The axial code may have remained the same from a descriptive code or piece of primary data which most supported all data found within this category. In this coding cycle, 13 axial codes were created and 27 descriptive codes were sifted out due to lack of connection to data. The connections of the axial codes to the descriptive codes were displayed in Figure 5, which is a sample flow chart using connecting words to create complete thoughts about how the descriptive and axial codes are connected. The connection between the two codes are further represented through weighting the arrow which connects the two codes. A complete list of connections between axial and descriptive codes can be found in Appendix D. Then, based on the research question, axial codes were synthesized and grouped together based on their ability to answer the research questions. Focused codes which succinctly synthesize the narrative created by the axial codes were generated. The focus codes were supported by the descriptive codes and the primary data which was nested below the axial code. Several displays of exemplar primary data related to the focused code were given. Codes during all three cycles rely on my subjectivity, which aligns very closely with the most common participant in the survey. For context, the number of respondents was very small as compared to the number of individuals invited, and the findings represent a theory based on these data. The findings do not represent a complete comprehensive picture of all Kentucky teachers and should not be interpreted as such. Conclusions of how these data may be utilized or what impact they have on future research is discussed in Chapter V.

CHAPTER V

DISCUSSION

The purpose of this study was to utilize public comments from mostly teachers which illustrate the challenges in implementing the NGSS in Kentucky classrooms to better determine the effect the standards have in teaching and learning science. From this analysis, the study would inform teachers, administrators, district personnel, and curriculum writers concerning the common challenges and suggestions to avoid those challenges. The study's framing illustrates the importance of teacher feedback upon influencing policy and adjusting instruction (Bondie, Dahnke, Zusho, 2019). Therefore, the utilization of targeted feedback concerning the challenges of implementing the NGSS should be studied.

Researcher subjectivity played a pivotal role in the analysis of the feedback utilized. It is important to note, not only is researcher subjectivity important to the results of the study (Sinclair, Cuthbert, & Barnacle, 2014), but in this study it was critical as the demographic and experiences of the researcher very likely matched the demographic and experiences of the most common participants. In his current position in a large urban Kentucky district, he is able to observe first hand science classrooms and witness evidence of the challenges of NGSS implementation. Acknowledgement of this subjectivity, and the emphasis of using it, further increases the trustworthiness of the study and the importance of the insights garnered.

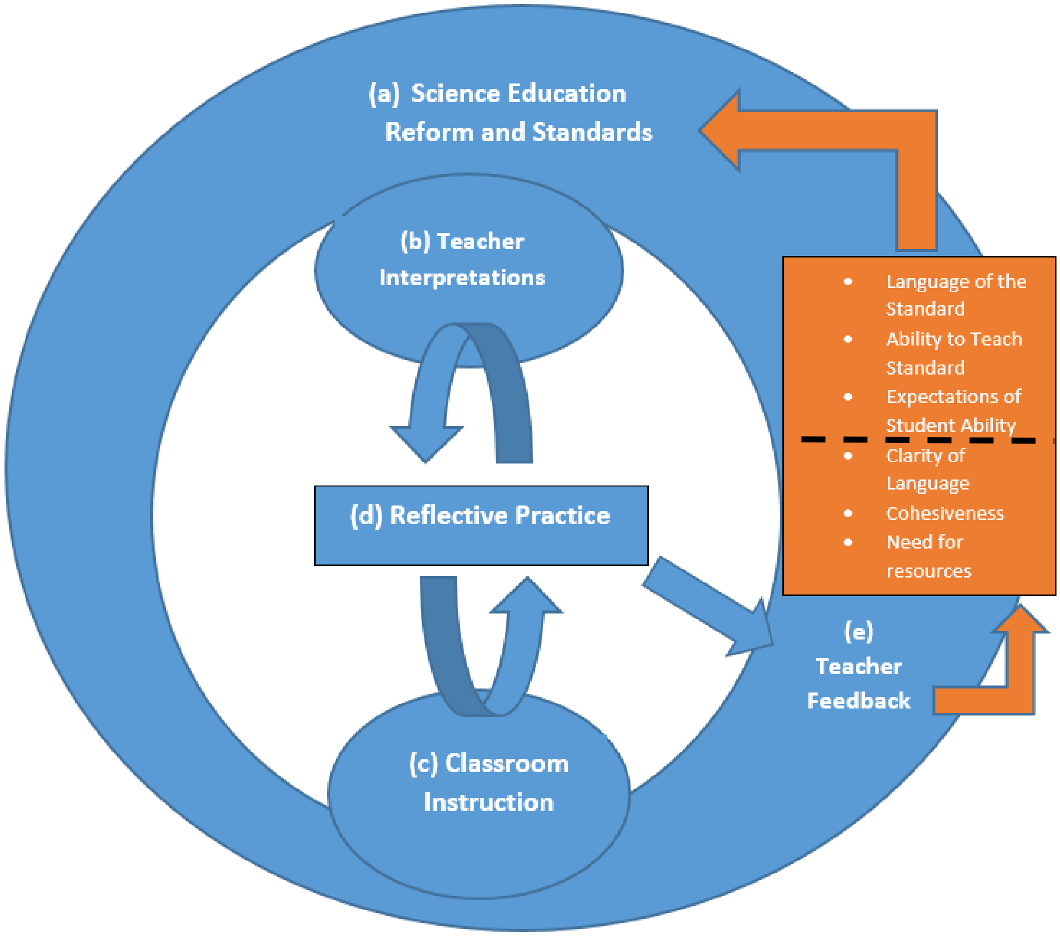
Focused codes which emerged from the analysis represent a theme supported by the study's primary data (stakeholder comments), descriptive codes, and axial codes. The comments are only from a small portion of invited participants, and should not be viewed as the opinion of all Kentucky teachers. During analysis, all individual comments were weighted equally in the creation of codes. Aligning with Erickson, (1986), the data corpus was systematically searched to ensure all comments were analyzed. From the 1,037 individual comments 4 were classified as positive by the Region 5 Comprehensive Center. These comments disconfirmed the assertions made in the focus codes; however, the preponderance of evidence shows the assertions were supported. For example, in the focus code, language of standard, most teachers stated the standard lacked clarity, specificity, and believed they were unable to understand the intent of the standard. However, there was one stakeholder who thought differently. In their comment "I think the way this standard is written is open for interpretation" they state the ambiguity of the standard is a good thing for science education. This study took into account potentially disconfirming comments and analyzed them against the rest of the data corpus. The focused codes which resulted from the analysis exhibit warranted answers to the study's research questions.

In the following sections the previously described focused codes are discussed, with an emphasis on describing potential solutions as well as suggestions for future research. Additionally, I present a revised conceptual framework based upon the study's emerging themes, which were driven by the development of focused codes. Revision was necessary because the data supported enhancing two constructs within the original framework: interpretation and feedback.

Revised Conceptual Framework

Within Figure 7, the construct *teacher feedback* has been revised. The revised model augments this construct by displaying what participants, presumably teachers, would like the authors of the NGSS to know in order to hone future standards. The revised model illustrates teacher challenges with interpreting the NGSS standards, or specifically their challenges upon reading the NGSS and assuming its intent. These suggestions for improvement probably occurred after instruction and reflecting upon their practice. Data related to teacher interpretation and teacher feedback provide answers to both of the study’s research questions, which can now be summarized within the revised model in Figure 7 below.

Figure 7. Augmented Conceptual Framework featuring conceptual categories of teacher feedback to influence reform.



Augmented conceptual framework illustrating science standard reform via teacher feedback and conceptual categories enhancing feedback (Trzaskus, 2022).

The revised model presents three factors (above dashed line) which ultimately influenced participants' interpretation of the NGSS, all of which highlighted the more challenging aspects of implementing the NGSS. Likewise, three factors (below dashed line) were mentioned by participants aimed at improving the NGSS. With these additions, the revised model represents a more nuanced problem space from which future research could stem.

From the revised model, the study's participants have espoused challenges with the NGSS both before and after instruction. Prior to instruction teachers believed there was a layered problem with the implementation of the NGSS. First, the language of the standards was complex and not easily understood by teachers. The misalignment is very troubling to teachers as they may not be educating students on the intent of the standard. Second, teachers are concerned they may or may not have the ability to teach the intent of the standard. This factor adds another layer of challenges in implementing the standard because, if the teacher understood the language they may not be teaching the standard with fidelity. Third, the expectation of student understanding or having a sensemaking experience with the standard concerned teachers. Many teachers commented on the lofty nature of the standards and their assumption that many students would not be able to achieve those goals. This final layer completes the concerns and may likely be more situational due to teachers and students being absent from classrooms because of the pandemic the year prior to the survey.

Teachers had more concerns post-instruction as well. The revised model shows three factors that may improve instruction of the NGSS when teachers implement the lesson again. The first factor to improve future instruction would be to have more resources to teach the standards. Resources could be supplies, curriculum aids, technology, data, and assessments, and teachers mentioned all of these as suggestions to make instruction easier. Second, the clarity of the language of the standard, the assessment boundary, the tools to aid in teaching, and the appendices of the NGSS are not viewed as being helpful to students or novice teachers. This disconnect illustrates the suggestion teachers have in rewriting the standards. Teachers believe they understand the intent of the standard, but the language is still very difficult to summarize after a lesson. Third, teachers commented on a lack of cohesiveness between the standards. Teachers commented on how standards should be bundled in different ways and how some content of standards appeared to assimilate better with other content. Furthermore, they commented on moving standards to alternate grades to further create cohesion.

Each one of the factors of the revised model is important and likely related to other factors. This relationship between pre and post instructional factors is very strong. It is possible the cycle is self-perpetual, by which, if a factor such as resources is unaddressed, then teacher ability may be negatively impacted as well. In the following sections, each factor is explained in more detail, as well as their connection to each other as well as to research and practice.

Conclusions for research question one—challenges of implementation

Focused codes for research question one

Challenges in implementing the NGSS included the clarity of the standard, teachers' ability in implementing the standard, expectations of students' ability to master the standard. The codes represent a range of issues within the implementation of the NGSS, with many possible causes. Given the limitations of the data set, it is not possible to explore the source of these root causes; however, each focused code is addressed independently and equally. It is likely the challenges are interrelated as lack of clarity can lead to reduced (teacher) ability to implement and lower (student) expectations on achieving the standard (Heritage, 2021). This echoes the sentiment of Perry & Lawrence, (2017), who hypothesized teachers had lower expectations of students being capable of mastering the SEPs.

Language of standard

The first issue participants had with the NGSS was the complex level of the standards expected from both teachers and students. Teachers who translate the standard into instruction were often left confused based upon the highly technical writing of the standard, presumably to remove ambiguity by the authors. The purpose of the NGSS is for students to become scientifically literate through the practice of doing science. However, the lack of pedagogical practice teachers have in applying the practices of the NGSS in their classroom instruction makes implementation a challenge. Most teachers would agree application of content indicates a high level of student comprehension; however, if those implementing the standard (the teachers) do not understand or have an example of what the scientific practice looks one can presume the resulting student comprehension will likely be lacking (Hudson, 1991). This problem reflects the language present in the NGSS which changes the content focus of phenomena being explained to phenomena being explored. This significant change can likely lead to confusion about the intent of the standard especially with novice teachers.

A longitudinal study involving elementary science teachers developing knowledge of science practices found they had low to moderate understanding of how to utilize creating models in their instruction (Bismack, Davis, Palincsar, 2022). The lack of understanding models extends to preservice elementary teachers as well (Ricketts, 2014). As these studies note, and in addition to the current study’s findings, the science and engineering practices continue to be challenging to implement in the classroom.

According to teachers' interpretations, the way a given standard was written was confusing. The NGSS utilizes three-dimensional learning: disciplinary core content, science and engineering practices, and cross cutting concepts. Based upon multiple comments, teachers showed a lack of understanding on how to teach the NGSS because they focused on the SEP. None of the comments made by teachers referenced the three dimensional nature of the standard. By focusing on SEPs, teachers were naïve to believe they were teaching all of the standard (You, 2017). Teachers focusing on just the verbs or practices could be a major hurdle of classroom instruction. Future research might consider the feedback provided by teachers as a method for removing this hurdle.

Another challenge to this hurdle is there is very little professional development of NGSS practices available to teachers (Allen & Penuel, 2015). Teachers point this out as well stating, 'I'm not sure how to accomplish this especially since I have very little knowledge of this field. There needs to be training offered in this area." This stakeholder comment, potentially from a teacher, summarizes a form of discomfort this participant had with the language of the scientific practice of the NGSS. In order for teachers to emphasize the science practices of the NGSS, they need to understand the scientific practices themselves (Bybee, 2014).

Possible solutions to alleviate this challenge

Several supports exist for teachers to overcome the challenges of implementing the NGSS and its related PEs (Windschitl et al., 2014). A single PE provides little guidance as to how a teacher might design lessons and enact instruction; therefore, multiple supports have been developed (Windschitl et al., 2014). Professional development can support some teachers though limited time and other resources for such supports make this an impractical solution to satisfy the needs of teachers across all grades and science disciplines.

NRC produced tools

Teachers using the NGSS face new challenges and need examples of what effective instruction and curriculum might look like (National Research Council, 2015). Responding to this, Achieve, a partner in organization in the development of the NGSS, stated materials will be needed to provide an extensive range of supports (NRC, 2016a). These resources do provide outlines as to what effective NGSS instruction looks like in the classroom; however, the onus is on the teacher to follow the steps necessary in creating a NGSS-aligned lesson. The work associated with creating an NGSS-aligned lesson may cause teachers to be unwilling to put out the effort. For example, one resource was the EQuIP Rubric for Lessons and Units: Science, which is designed to evaluate lesson sequences or units for NGSS-alignment (Achieve, 2016a). Also Achieve released a reduced version of the EQuIP rubric, called the *NGSS Lesson Screener* (Achieve, 2016b). These two resources, because of their student and teacher support, can be classified as an educative curriculum (Roseman, Herrmann-Abell, & Koppal, 2017).

Educative Curriculum

According to Achieve, to help teachers understand the new standards and implement them effectively, materials will need to provide an extensive range of supports, from suggestions for how to engage students in developing explanations and constructing conceptual models of the natural world to learning progressions that map out students' development of science content knowledge over time (2015). Because of their widespread use by teachers (Horizon Research, 2012), curriculum materials that are educative have enormous potential for leveraging teachers' role as translators of standards and reforms such as those proposed by the NGSS to the classroom (Ball & Cohen, 1996; Remillard, 2005). However, if a teacher is unaware of these resources they may continue to struggle in creating NGSS-aligned lessons

Other resources found within the body of the NGSS are available to help teachers alleviate their confusion over the meaning of the NGSS. The most pronounced is the performance expectation and assessment boundaries attached to each standard. The two resources are printed with the full written standard to guide teachers to the meaning. The performance expectation is of particular importance as the outcome merges the science and engineering practice and content into what the teacher should see students doing in the classroom. Furthermore, these resources were created specifically for teachers to clarify the intent of the standard and bound it to a particular content goal in the classroom setting (Pellegrino, Wilson, Koenig, & Beatty, 2014). If teachers were likely more aware of these resources or had professional development focusing on how to use these resources, standard translation could be more successful and lead to classroom instruction reflecting the standard. Teachers being unaware of these resources poses more questions such as, are the resources advertised in professional development trainings; are there free resources to assist in utilizing the resources; and are exemplar lessons available for teachers to model after?

Translation of the standards from technical scientific language to more teacher-friendly language could suffice to alleviate the challenge, but participants in the study showed very little awareness of these resources or disagreed with what was being proposed in the resource. Utilizing the resources designed by the authors of the NGSS though, would be a highly effective avenue to alleviate the challenge of clarity espoused by the feedback of the participants. The resources are free, and available to all those that participated in the survey. Other free resources are located at https://www.nextgenscience.org/resource-library, which includes the EQuIP rubric and facilitation guide, and a deeper set of clarity statements which contains observable measurable statements on what students should be able to do. Although this is not an exhaustive list, it could potentially alleviate many of the issues of clarity which teachers have in implementing NGSS. The list of resources can be found on the NGSS home webpage, and is prominent and extensive. Perhaps due to the extensive nature of the resources some teachers may not believe they have time to explore them, but this would need to be followed up with further research.

Another NGSS designed resource is the Appendices for the standards, specifically Appendix F. This resource translates the student expectation of the scientific practice of the standard, provides a rationale or relevance, and scaffolds the practice for different grade bands. The participants' reaction to this resource was negative as well. Comments were made concerning the language of the appendix, the unnecessary nature of having multiple sources to teach the lesson, and complaints students could not achieve the levels suggested within it. The resistance to utilizing resources could be reflective of teacher burnout, or lack of time to explore the resources as mentioned previously.

Professional development can alleviate challenges of the NGSS by providing sensemaking opportunities to align the intent of the NGSS, curriculum, and assessment (Allen & Penuel, 2015). The training necessary should be continuous, focused on content, and learner focused for the best results (Postareff, 2007). Finding, or even developing this training for teachers to understand how to teach in all three dimensions is not commonly found. The vast majority of professional development in the post Covid pandemic has examined social emotional learning and remote science education, neither being an impetus of the NGSS (Hartshorne et al., 2021). In order to develop more understanding of the NGSS, professional development should be utilized, and the training may also alleviate the challenges of teacher ability as well.

Potential solutions of appropriate professional development could include science backward design. In this professional development teachers would start with the performance expectation and assessment boundary and work backwards in building their lessons and learning targets for those lessons. Another solution could include teacher immersion in scientific practice. With this professional development teachers would have scientific practices modeled to them by a field scientist. Then, the teachers would be able to partake in the practices and translate how the practice can be utilized in the classroom. Finally, especially for novice and elementary teachers who likely lack a science background, using professional development designed around breaking down the standard. The NGSS has a large amount of information present on each standard, but a more targeted approach of what each dimension looks like within the classroom could aid in understanding the standard. Although many resources exist to help some teachers, based on the feedback obtained, teachers are struggling to find access to these resources to achieve their goal of student understanding.

Ability to teach standard

Closely linked to clarity, teacher ability is a concern teachers had regarding implementation of the NGSS. The NGSS standards are rich in scientific knowledge and application. However, in Kentucky, there are many different avenues to becoming a teacher, and in this case a science teacher. As of March 2022, there were fifteen different avenues for becoming a Kentucky teacher all with varying requirements. Some of these requirements do not require the teacher to have any experience with science, experience within a classroom, or experience attending a teacher certification class in person.

The lack of specific science classroom training illustrates the teachers' concerns they may not be capable of teaching to the intent of the standard. Preservice elementary teachers consistently lacked using scientific practices in explaining how scientific knowledge was obtained (Zangori & Forbes, 2013). Not utilizing the scientific practices leaves teachers at a disadvantage to effectively modeling and teaching the practices (Lauderdale-Littin & Brennan, 2018). Furthermore, the lack of preparation of science pedagogy or knowledge of scientific practices could lead to lower self-efficacy of teachers' abilities (Hammock & Ivey, 2017). Lower confidence in the content or SEP may give rise to frustration and could lead to blaming the NGSS for teacher lack of preparation and perceived ability.

Possible solutions to alleviate this challenge

Teacher shortages across Kentucky have been well documented and increasing in the last five years (Sutcher, Darling-Hammond, & Carver-Thomas, 2019). This national workforce crisis has left legislative bodies scrambling to enact new ways to slow this process. In Kentucky, there are multiple avenues to becoming a certified teacher, and most are non-traditional tracts, some of which include partial certification with an extended time-line for achieving full certification. While it is important to allow multiple pathways for teacher certification, these pathways are not without drawbacks in terms of creating effective teachers.

One of the drawbacks is voiced by the teachers. If teachers believe their ability to effectively teach the NGSS is lacking, then perhaps taking a closer look at policy for science teacher certification is a solution. Teachers who complete one of the non-traditional avenues of teacher certification would not be starting their classroom experience at the same level of science knowledge or pedagogy as a traditional track teacher. The lack of preparation some of these avenues provide is further compounded by the fact new teachers receive varying levels of support within their building (Koller, Osterlind, Paris, & Westin, 2008). Teachers, even experienced science teachers, would likely question their ability, not understand the intent or language of the standard, and not have time to search and understand resources. Therefore, a novice teacher, with a novice understanding of science, who does not receive necessary support may not have the ability to implement the NGSS, and this is a concern of the teachers.

One potential solution for these novice teachers would be directed professional development. At this time, there is no content requirement for many of the districts in Kentucky and teachers are allowed to pick and choose their professional development training. Furthermore, there is no guarantee there are NGSS focused professional developments offered, or even science content or pedagogy supporting science teaching. Because of this, it is unlikely novice science content or experienced teachers could increase their knowledge base and therefore their ability to implement the NGSS. So, it stands to reason that increasing the number and types of professional developments for Kentucky science teachers to engage in practices aligning the NGSS, content, and pedagogy would close the gap. In doing so, there is potential to increase the confidence level of Kentucky science teachers and their perceived ability to teach the NGSS.

Expectations of Student

Students were not included at any time within this study; therefore, an accurate representation of their academic ability was not determined. However, from the teachers' input, there is a clear connection between the assumed rigor of the NGSS and assumed abilities of students. The concern from the teachers is students cannot meet the challenges put forth by the NGSS as the language of the standards is too scientific or the practices too complex.

Due to the Covid-19 pandemic, there were significant losses of classroom instructional time; however, accountability of students, teachers, and schools were not altered until after the survey was closed. The resulting low expectations are significant as students, especially students of color, underachieve due to these expectations (Moore, 2005). Underachievement then becomes a culture in the classroom and teachers continue to lower their expectations of students creating a cycle of underachievement in the classroom (Cleveland, 2011). Expectations for students may have been higher if continuous learning was in place. Therefore, these expectations may be more situational than unalterable.

As student achievement is a marker of successful classrooms, achievement, or lack thereof, is feedback which is also related to teacher ability. The focus code discussed here may, in fact, be more directly related to teacher ability, but further research would be necessary. However, solutions which positively influence teacher ability such as focused professional development, more pedagogical training, and knowledge of resources available may alleviate the challenge of implementing the NGSS.

Possible solutions to alleviate this challenge

Possible solutions, specifically related to students and not to teacher ability, are included in this section. These solutions are more systemic than classroom specific. One way to break a cycle of underachievement based on lowering expectations, teachers should rework their classroom operations to create a more inclusive culture (Snell & Lefstein, 2018). The NGSS authors have created many resources to be used on improving the culture of the classroom, most of which focus on inclusive aspects of pedagogy and high-yield instructional practices. Furthering these, are content resources, these content storylines allow teachers to provide a culturally inclusive story to anchor student learning. The storylines are available for all grade bands and reference the standard(s) addressed via the storyline. Also case study examples, written by teachers, on how to include a diverse group of students at different levels into a science classroom with specific lesson plans are present on the NGSS resources web page (NGSS online resource library page https://www.nextgenscience.org/resource-library).

Leadership in the school building is needed to change a cycle of underachievement. Positive reinforcement of students, staff morale, and a mindset of continuous improvement should improve the cultural norms of a school (Lindsey, Nuri-

Robbins, Terrell, & Lindsey, 2018). Unfortunately, leadership within a school can vary as much as the level of teaching effectiveness. However, strong leaders would create better cultural norms within the school and improve staff performance by assisting teachers with selecting professional development, celebrating their accomplishments, and listening to their concerns. Through effective leadership, the culture of the school can improve, leading to higher expectations of students, and higher student achievement.

Research question two—suggestions for improvement

Focused codes

The focus codes which emerged to answer the second research question called for improvement of the implementation of the NGSS in three different ways; need for resources, rewriting the standards, and moving the standards to create a more coherent storyline for students. The suggestions for improvement ranged from broad reasons; to very specific localized needs. As the degrees of specificity vary greatly within each of the focus codes, so do the action steps I suggest to aid in the implementation.

Need for resources

Although lacking resources does not reflect any suggestion about the NGSS, this theme remains relevant as resources are necessary for the implementation of the NGSS (NAS, 2016; Reiser, 2013). Resources, or lack thereof, have often been a challenge for education. Initiatives and policies enacted are underfunded or not funded at all causing a significant strain on school budgets and student outcomes (Douglass, 2010). Regardless of budget constraints, teachers still can request resources to provide students with better classroom experiences. Many of the requests (e.g. access to a freezer to store specimens) could be placed into a budget if the teacher feels capable of asking their administrator. Furthermore, when budgeting requests have been denied, there are other avenues to gain funds such as philanthropic organizations, grants, or participation in approved curricular development. Often, with district and administrator approval, teachers are able to create “Go Fund Me” pages to be used for specific classroom needs.

Other resources may be present and free, but not advertised to teachers who may be new to their district or school. In these cases, asking more experienced teachers or administrators may alleviate the challenge of not having necessary resources. Non-profit or other scientific community websites may contain data necessary for a robust lesson. One such foundation is Science for Society and the Public which focuses on increasing scientific literacy through helping teachers and students gain resources to enhance learning. A more localized opportunity to teach science without additional resources would be altering lesson plans to create a different way for students to achieve the performance expectation of the standard. Altering lesson plans actually provides an opportunity for teachers to obtain a more complete understanding of their students’ abilities (Tomlinson & McTighe, 2006). Through reflecting and asking other science educators, (in building, district, or professional organizations) limited resources, may not be as much of a barrier because innovative ways at assessing the standard would be possible.

The lack of resources in the classroom perpetuates a cycle of challenges related to implementing the NGSS mentioned by teachers. The missing resources to engage in the scientific practice of modeling or data analysis inhibits teacher ability. The inhibition of ability likely leads to a lowering of expectations of students as the teacher does not see students measuring up to the performance expectations (Brophy, 1983). The self-fulfilling prophecy of no resources means no positive outcomes, also affects teacher efficacy and their expectations of their students, and future students (Jussim, 1989). Due to the harmful potential of this path, more resources should be given to or made known to science educators in Kentucky, because teachers believe there are not enough resources almost ten years after NGSS was implemented by the state.

Clarity of Language

The NGSS went through a significant revision process which included feedback from multiple groups prior to being released to states for adoption. Kentucky was one of the NGSS Lead States and an early adopter of NGSS. To completely rewrite the standards for one locale would not be appropriate; however, as Brown, (2009) states local adaptations are warranted in enacting curriculum; therefore, smaller focused rewrites of the standard to aid in student and teacher understanding may be warranted.

The feedback from teachers regarding how to rewrite the NGSS should serve as an insight to their understanding of the standard. It is entirely possible teachers have a novice understanding of science, and are unable to correctly interpret the technical language of the science and engineering practices. In this way, confusion by teachers is possible as engineering language is defined through other technical language. The authors of the NGSS would benefit from heeding this feedback concerning the language as not all science teachers have experience in science or engineering practices (Cunningham & Carlsen, 2014). This inexperience with science practices likely leads to other frustrations of teacher ability and perpetuates the cycle.

The writing of the standards, as well as their explanations, using only technical language leaves them less understandable to novice teachers and to students. Both groups, as well as some experienced teachers, do not understand the fundamental principles of being a scientist or engineer (Atink-Meyer & Meyer, 2016). As such, writing the standards with technical language (for accuracy) can become frustrating for those groups not familiar with the terminology. It should be noted the NGSS appendices do unpack the SEPs for each grade level, but teachers may not be aware of the resource. The potential rewrite, or other actions to improve the clarity of the NGSS should be seen as opportunities to improve science understanding and relevance, not as criticism, as teachers believe the standards would become less intimidating to both students and novice teachers.

Once again, the use of more focused professional development with the NGSS and its intent would serve teachers well. The clarity of language appears to be directed mainly at the verbs indicating the SEP the standard is asking students to achieve. Disciplinary core content and cross cutting concepts are also aspects of the NGSS which should be taught in conjunction with the SEP to create scientifically literate students. Teachers appear far more confident in their understanding of patterns, cause and effect, and scale and proportion, all which are cross cutting concepts to be revisited in all levels of science teaching (Bismack, Davis, & Palinscar, 2022). Professional development which incorporates more in depth understanding and modeling of the SEPs would benefit teachers the most. This training likely would increase teacher ability as they would have greater confidence in the intent of the standard. Then, the cycle of the revised framework would perpetuate and likely produce more positive student outcomes.

Cohesiveness

Conceptual change is a learning theory in which the student undergoes a shift in knowledge or beliefs about scientific phenomena which integrates with existing knowledge. The more misconceptions or faulty knowledge the student has surrounding the phenomena the more drastic the conceptual change can be (diSessa & Sherrin, 1998). One way to promote conceptual change easily is for teachers to adhere to a coherent science storyline, which helps students anchor their thinking (Brown & Hammer, 2009). Mirroring this methodology, the NGSS utilizes conceptual change to aid students in learning science through doing science. Therefore, creating a coherent story line for students becomes important for the effective application of the conceptual change learning theory.

Teachers who had concerns about cohesiveness believe the NGSS is disjointed in its progression and both students and teachers cannot follow its intended storyline. The NGSS advocates for coherence in the content story line by bundling performance assessments, and the authors of the NGSS provide a resource for teachers to help bundle the standards and create a storyline. However, the work of making connections between the performance expectations and the lessons fall solely on the teacher. Furthermore, the authors provide the resources for content storylines of the NGSS does not attempt to connect content topics but merely illustrates the importance of the performance expectation with the topic. Although several resources are provided none of them truly accomplish creating the coherent storyline. The stakeholder's frustration, most likely from a teacher, is exhibited through responses claiming they (teachers) should not need to have multiple resources in order to understand the intent or progression of the standards.

Teachers believe conceptual change is necessary as many students come to school with misconceptions of science (Vosniadou, 2012). Specific stakeholder suggestions were made to create a more cohesive storyline which presumably were from teachers who subscribe to the theory of conceptual change. Many believed moving similar standards, for example Newton's Laws, all to the same grade band and in succession would help in student understanding. Others, likely teachers, believed delaying standards in order for students to be exposed to the necessary math procedures would be best. This frustration appears to be with the lower levels of achievement students are having in science classes.

Data indicated teachers did not believe students were able to achieve the intent of the standards; therefore, their frustration led them to suggest altering the standard progression. By placing the onus on themselves, teachers voiced their frustrations with the storyline as they believe there are few examples to aid this process. Suggestions, other than moving standards, included breaking apart or combining standards in order to scaffold the story line for coherence. These suggestions have merit; however, the teachers assume a science or engineering practice, or content standard is a stand-alone practice. Authors of the NGSS wished for student growth within the practice of science in order to create meaningful conceptual change. In this manner, stakeholder suggestions, possibly from teachers in the classroom, for breaking or combining standards is misplaced as individual standards are not the end goal of a lesson, but rather a starting point to increase student exposure to science.

Another misplacement of frustration against the NGSS should be directed at the state level education policy body or local district. The order in which teachers are asked to present the standards to their students is not prescribed by the NGSS, rather it comes from the state or the curriculum the district utilizes to teach the NGSS. Teachers could be better served by first analyzing their curriculum and addressing its incoherence, which may be out of date in both content and process. By focussing on the curriculum and not the standards used to create curriculum, teachers could find a more appropriate space to vent frustration.

Implications of this study

This study has implications for both research and practice. The Kentucky Department of Education is the primary audience for this work as they were the group asking for feedback. Next, district administrators and policy makers should meet with teachers to learn more about the suggestions they present and how to implement them. Another intended target is teacher educators, as they may look to this research to help newer teachers avoid the frustration espoused by practitioners. Finally, current teachers should review this study for possible solutions to their issues provided by their colleagues.

In terms of research, decision makers regarding curriculum and standards should take more time to listen to those who are asked to enact the curriculum. Feedback from reflective practice is a powerful lens into the successes and challenges of school implementation; however, it is often overlooked in favor of student achievement data (Ostermann & Kottkamp, 2004). While important, student achievement is after the enactment of curriculum datum that does not take into account the mediating factor of how the curriculum was enacted. If teachers experience consistent challenges regarding their implementation of the standards, perhaps a closer look into the standards themselves is warranted. In this study, teachers were asked to provide their reaction to the standards and they primarily espoused challenges related to their implementation. This result should be somewhat alarming as some Kentucky science teachers in Kentucky do not believe they have the right support to implement the standards correctly. Furthermore, the lack of teacher feedback in curriculum studies should also be addressed, and included as part of a robust research study concerning the implementation of curriculum.

In terms of practice, this study shows how reflection, feedback, and instructional adjustments remain a critical component of teaching. Standards may not be able to be altered directly, or quickly, but the rigidity of the standard presents a great opportunity for teachers to be flexible and to reflect on their lessons and adjust to meet student needs. According to teachers, one of the primary concerns of the NGSS was the rigor for students. If the rigor was unattainable due to resources or clarity, teachers have opportunities to innovate new ways of teaching the NGSS. If effective, they can, in turn, create a curriculum supporting all students. So, in practice, a high rigor level may be seen as negative, but it may be a positive for innovation in the classroom.

Considerations for future research

Future Potential Participants

Within qualitative research data saturation may become necessary when constructing new conceptual ideas. The current study utilized data collected by an agency other than the study's primary investigator. Due to this limitation, theoretical sampling from the study's original set of participants was not possible. Therefore, additional data or theoretical sampling was considered in order to add evidence to the emerging theme or themes. Future studies should involve, identifying, and selecting additional participants for semi-structured interviews and/or open-ended questionnaires (Patton, 2004). Participants could be solicited from throughout the state. All questions would be geared towards the emergent theme or themes emerging from the study's initial analysis. For example, if an emergent theme arose related to teacher licensure and preparedness, participants might be asked to discuss their feelings related to this topic.

Feedback is a critical component in learning as it informs us what aspects of practice are working, what is challenging, and what can be improved. This research sets a foundation for the importance of obtaining feedback regarding the NGSS. Future avenues of research should pursue the interventions in response to the challenges voiced by the teachers. Professional development is an intervention that can be used to inform teachers in science and engineering practices. Helping teachers better understand targeted science concepts may make them more comfortable with what is expected of students. Creation of lesson plans and examples of coherent storylines may represent another intervention in response to the lack of clarity in the NGSS. Once any of these interventions is completed, effectiveness of the change might be demonstrated by soliciting additional feedback from the teachers. The feedback may include surveys in which participants are identified for follow up interviews, focus groups which concentrate their discussion on an emergent theme, or classroom observations to aid teacher reflection on their science and pedagogical knowledge. A large body of research could be obtained by including feedback from students. This future body of research should be compared to this study to see if the challenges faced by students are the same as the original teachers.

A separate but also important note to make is the timing of the survey, January 2021, during school shutdowns and virtual learning. Responding to this international event, schools were more focused on equitable access to technology and social emotional learning as opposed to professional development aimed at increasing the ability to teach science. As a result, instructional practice likely suffered across all contents, but may have been more pronounced with the active learning necessary in the NGSS. The inability for teachers to engage their students in doing science in a virtual classroom can cause doubt in ability. Doubting, may again lead to lower self-efficacy and therefore frustration and blame being espoused for the standard as opposed to teachers' own abilities. Data collected at a different point in time could lead to different comments.

A final avenue of research would be to utilize the redesigned model conceptual framework to find nuance within the focused codes. In addition to utilizing the new framework, adding more coders would change the frame of the subjectivity. Coders of different backgrounds could provide a more complete picture of the challenges. The challenges may become nuanced enough to determine which of the previously emerging challenges is more consequential or influential. Furthermore, changing the coders but not the framework aids research by developing interpretations of data which may not have emerged otherwise. Furthermore, the suggestions for improvement may be heeded if the opinion does not come from one professional, but rather a body of professionals.

REFERENCES

Achieve (2014). State Science Education Standards Comparison Tool (Version 1). Author: https://www.nextgenscience.org/sites/ default/files/Standards%20Comparison%20Tool%20July%201%202014.pdf

Achieve (2016). EQuIP rubric for lessons & units: science (Version 3.0). Author: https://www.nextgenscience.org/sites/default/files/ EQuIPRubricforSciencev3.pdf

Achieve (2017). Primary evaluation of essential criteria (PEEC) for Next Generation Science Standards instructional materials design (Version 1.0). Author: https://www.nextgenscience.org/peec

Allen, C. D., & Penuel, W. R. (2015). Studying teachers' sensemaking to investigate teachers' responses to professional development focused on new standards. *Journal of Teacher Education*, *66*(2), 136-149.

Alonzo, A. (2013). What can be learned from current large-scale assessment programs to inform assessment of the Next Generation Science Standards? Paper presented at the Invitational Research Symposium on Science Assessment, K-12 Center at ETS.

American Association for the Advancement of Science. (1989). Project 2061: Science for all Americans. New York: Oxford University Press.

Andrews, D., Nonnecke, B., & Preece, J. (2003). Electronic survey methodology: A case study in reaching hard-to-involve Internet users. *International journal of human-computer interaction*, *16*(2), 185-210.

Arias, A. M., Davis, E. A., Marino, J. C., Kademian, S. M., & Palincsar, A. S. (2016). Teachers' use of educative curriculum materials to engage students in science practices. *International Journal of Science Education*, *38*(9), 1504-1526.

Atkin, J. M., & Black, P. (2007). History of science curriculum reform in the United States and United Kingdom. In *Handbook of research on science education* (pp. 781-806). Taylor & Francis.

Antink-Meyer, A., & Meyer, D. Z. (2016). Science teachers' misconceptions in science and engineering distinctions: Reflections on modern research examples. *Journal of Science Teacher Education*, *27*(6), 625-647.

Aronson, B., & Laughter, J. (2016). The theory and practice of culturally relevant education: A synthesis of research across content areas. *Review of Educational Research*, *86*(1), 163-206.

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform?. *Educational researcher*, *25*(9), 6-14.

Banilower, E. R., Smith, P. S., Malzahn, K. A., Plumley, C. L., Gordon, E. M., & Hayes, M. L. (2018). Report of the 2018 National Survey of Science and Mathematics Education. Horizon Research, Inc. (NJ1).

Banks, J. A. (1991). A curriculum for empowerment, action, and change. *Empowerment through multicultural education*, 125-141.

Barnette, E. J. (2003). The role of technology teachers in ensuring standards-based programs. *Technology and Engineering Teacher*, *62*(7), 32.

Baron, C., Sklarwitz, S., Bang, H., & Shatara, H. (2019). Understanding what teachers gain from professional development at historic sites. *Theory & Research in Social Education*, *47*(1), 76-107.

Becker, K. H., & Park, K. (2011). Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. *Journal of STEM education: Innovations and research*, *12*(5).

Behrend, T. S., Sharek, D. J., Meade, A. W., & Wiebe, E. N. (2011). The viability of crowdsourcing for survey research. *Behavior research methods*, *43*(3), 800-813.

Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education*, *95*(2), 191-216.

Berland, L. K., Schwarz, C. V., Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2016). Epistemologies in practice: Making scientific practices meaningful for students. *Journal of Research in Science Teaching*, *53*(7), 1082-1112.

Bismack, A. S., Davis, E. A., & Palincsar, A. S. (2022). Science practice-readiness: Novice elementary teachers' developing knowledge of science practices. *Science Education*.

Bismack, A., Davis, E., Palincsar, A. S., Arias, A. M., S., Marulis, L., & Iwashyna, S. (2014). Designing educative curriculum materials: A theoretically and empirically driven process. *Harvard Educational Review*, *84*(1), 24-52.

Bondie, R. S., Dahnke, C., & Zusho, A. (2019). How does changing "one-size-fits-all" to differentiated instruction affect teaching?. *Review of Research in Education*, *43*(1), 336-362.

Boyer Commission on Educating Undergraduates in the Research University. (1998). *Reinventing undergraduate education: A blueprint for America's research universities*. State University of New York at Stony Brook for the Carnegie Foundation for the Advancement of Teaching.

Brophy, J. E. (1983). Research on the self-fulfilling prophecy and teacher expectations. *Journal of educational psychology*, *75*(5), 631.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. Journal of the Learning Sciences, 2, 141– 178.

Brown, A. V. (2009). Students' and teachers' perceptions of effective foreign language teaching: A comparison of ideals. *The Modern Language Journal*, *93*(1), 46-60.

Brown, D. E., & Hammer, D. (2009). Conceptual change in physics. In *International handbook of research on conceptual change* (pp. 155-182). Routledge.

Bryan, L. A. (2003). Nestedness of beliefs: Examining a prospective elementary teacher's belief system about science teaching and learning. *Journal of research in science teaching*, *40*(9), 835-868.

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of science teacher education*, *25*(2), 211-221.

Cess-Newsome, J. (1999). Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction. In *Examining pedagogical content knowledge* (pp. 51-94). Springer, Dordrecht.

Chapple, M., & Murphy, R. (1996). The nominal group technique: extending the evaluation of students' teaching and learning experiences. *Assessment & Evaluation in Higher Education*, *21*(2), 147-160.

Charmaz, K. (1991). Translating graduate qualitative methods into undergraduate teaching: Intensive interviewing as a case example. *Teaching Sociology*, 384-395.

Charmaz, K. (2006). Constructing Grounded Theory. London: SAGE.

Chin, C. C. (2004). Museum experience—A resource for science teacher education. *International Journal of Science and Mathematics Education*, *2*(1), 63-90.

Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *45*(8), 922-939.

Cleveland, K. P. (2011). *Teaching boys who struggle in school: Strategies that turn underachievers into successful learners*. ASCD.

Coburn, C. (2001). Collective sensemaking about reading: How teachers mediate reading policy in their professional communities. Educational Evaluation and Policy Analysis, 23(2), 145–170.

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), New directions in educational technology (pp. 15–22). New York: Springer-Verlag.

Contreras, M. E. (2011). *The effects of teacher perceptions and expectations on student achievement* (Doctoral dissertation, UC San Diego).

Cresswell, John W. (2014). Qualitative, quantitative, and mixed methods approaches (4th ed.). Thousand Oaks, CA: Sage.

Cross, D. I. (2009). Alignment, cohesion, and change: Examining mathematics teachers' belief structures and their influence on instructional practices. *Journal of Mathematics Teacher Education*, *12*(5), 325-346.

Cunningham, C. M., & Carlsen, W. S. (2014). Teaching engineering practices. *Journal of science teacher education*, *25*(2), 197-210.

C. S. A. I. (2018). Standards Alignment to Curriculum and Assessment.

Czerniak, C. M., & Lumpe, A. T. (1996). Relationship between teacher beliefs and science education reform. *Journal of Science Teacher Education*, *7*(4), 247-266.

Dalton, R. J. (2013). *Citizen politics: Public opinion and political parties in advanced industrial democracies*. Cq Press.

Darling-Hammond, L. (2006). Constructing 21st-century teacher education. *Journal of teacher education*, *57*(3), 300-314.

Darling-Hammond, L., & Baratz-Snowden, J. (2007). A good teacher in every classroom: Preparing the highly qualified teachers our children deserve. *Educational Horizons*, *85*(2), 111-132.

Davis, E. A., & Krajcik, J. (2005). Designing educative curriculum materials to promote teacher learning. Educational Researcher, 34(3), 3-14.

Davis, E. A., Palincsar, A. S., Smith, P. S., Arias, A. M., & Kademian, S. M. (2017). Educative curriculum materials: Uptake, impact, and implications for research and design. *Educational Researcher, 46*(6), 293-304.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(6), 582-601.

Décieux, P. J., Mergener, A., Neufang, M. K., & Sischka, P. (2015). Implementation of the forced answering option within online surveys: do higher item response rates come at the expense of participation and answer quality?. *Psihologija*, *48*(4), 311-326.

DeMuth, C. 2016. “Can the Administrative State be Tamed?” *Journal of Legal Analysis* 8 (1): 121–190.

Deverka, P. A., Lavallee, D. C., Desai, P. J., Esmail, L. C., Ramsey, S. D., Veenstra, D. L., & Tunis, S. R. (2012). Stakeholder participation in comparative effectiveness research: defining a framework for effective engagement. *Journal of comparative effectiveness research*, *1*(2), 181-194.

DiSessa, A. A., & Sherin, B. L. (1998). What changes in conceptual change?. *International journal of science education*, *20*(10), 1155-1191.

Douglass, J. A. (2010). Higher Education Budgets and the Global Recession: Tracking Varied National Responses and Their Consequences. Research & Occasional Paper Series: CSHE. 4.10. *Center for Studies in Higher Education*.

Dudley, P. (2013). Teacher learning in Lesson Study: What interaction-level discourse analysis revealed about how teachers utilized imagination, tacit knowledge of teaching and fresh evidence of pupils learning, to develop practice knowledge and so enhance their pupils' learning. *Teaching and teacher education*, *34*, 107-121.

Duncan, R. G., Chinn, C. A., & Barzilai, S. (2018). Grasp of evidence: Problematizing and expanding the next generation science standards’ conceptualization of evidence. *Journal of Research in Science Teaching*, *55*(7), 907-937.

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM education*, *3*(1), 1-8.

Erickson, F. (1986). Culture difference and science education. *The Urban Review*, *18*(2), 117-124.

Fantilli, R. D., & McDougall, D. E. (2009). A study of novice teachers: Challenges and supports in the first years. *Teaching and teacher education*, *25*(6), 814-825.

Farrell, T. S. (2013). Reflecting on ESL teacher expertise: A case study. *System*, *41*(4), 1070-1082.

Finelli, C. J., Daly, S. R., & Richardson, K. M. (2014). Bridging the research-to-practice gap: Designing an institutional change plan using local evidence. *Journal of engineering education*, *103*(2), 331-361.

Forbes, C. T., & Davis, E. A. (2007, April). Beginning elementary teachers‟ learning through the use of science curriculum materials: A longitudinal study. In *Annual meeting of the National Association for Research in Science Teaching, April, New Orleans. Retrieved from: http://hice. org/presentations/documents/Forbes_Davis_NARST2007. pdf*.

Früh, Werner (1992). Analyse sprachlicher Daten. Zur konvergenten Entwicklung ‘quantitativer’ und ‘qualitativer’ Methoden [The analysis of verbal data: The converging development of ‘quantitative’ and ‘qualitative’ methods]. In Jürgen Hoffmeyer-Zlotnik (ed.), Analyse verbaler Daten. Über den Umgang mit qualitativen Daten [The analysis of verbal data. How to deal with qualitative data] (pp. 59–89). Opladen: Westdeutscher Verlag.

Fulmer, R., Joerin, A., Gentile, B., Lakerink, L., & Rauws, M. (2018). Using psychological artificial intelligence (Tess) to relieve symptoms of depression and anxiety: randomized controlled trial. *JMIR mental health*, *5*(4), e9782.

Fulmer, G. W., Tanas, J., & Weiss, K. A. (2018). The challenges of alignment for the Next Generation Science Standards. *Journal of Research in Science Teaching*, *55*(7), 1076-1100.

Gallagher, B. (1971). Generation of surf beat by non-linear wave interactions. *Journal of Fluid Mechanics*, *49*(1), 1-20.

Gay, G. (1988). Designing relevant curricula for diverse learners. *Education and urban society*, *20*(4), 327-340.

Gehrke, R. S., Cocchiarella, M., Harris, P., & Puckett, K. (2014). Field Experiences and Perceptions of Inclusion: Varying Contexts, Structures, and Interpretations. *Journal of the International Association of Special Education*, *15*(2).

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In *Examining pedagogical content knowledge* (pp. 3-17). Springer, Dordrecht.

Gess-Newsome, J., Taylor, J. A., Carlson, J., Gardner, A. L., Wilson, C. D., & Stuhlsatz, M. A. (2019). Teacher pedagogical content knowledge, practice, and student achievement. *International Journal of Science Education*, *41*(7), 944-963.

Glaser, B. (1978) Theoretical sensitivity: Advances in the methodology of grounded theory. Sociology Press, Mill Valley.

Glaser, B. G. & Strauss, A. L. (1967). The Discovery of Grounded Theory. Strategies for Qualitative Research. Chicago Aldine.

Goldman, S. R., Graesser, A. C., & van den Broek, P. (Eds.). (1999). *Narrative comprehension, causality, and coherence: Essays in honor of Tom Trabasso*. Routledge.

Groeben, N., & Rustemeyer, R. (1994). On the integration of quantitative and qualitative methodological paradigms (based on the example of content analysis).

Hammack, R., & Ivey, T. (2017). Examining elementary teachers' engineering self-efficacy and engineering teacher efficacy. *School Science and Mathematics*, *117*(1-2), 52-62.

Harlen, W., & James, M. (1997). Assessment and learning: differences and relationships between formative and summative assessment. *Assessment in education: Principles, policy & practice*, *4*(3), 365-379.

Harris, K., Sithole, A., & Kibirige, J. (2017). A Needs Assessment for the Adoption of Next Generation Science Standards (NGSS) in K-12 Education in the United States. *Journal of Education and Training Studies*, *5*(9), 54-62.

Hartshorne, R., Baumgartner, E., Kaplan-Rakowski, R., Mouza, C., & Ferdig, R. E. (2020). Special issue editorial: Preservice and inservice professional development during the COVID-19 pandemic. *Journal of Technology and Teacher Education*, *28*(2), 137-147.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research*, *77*(1), 81-112.

Henry, G. T., & Mark, M. M. (2003). Beyond use: Understanding evaluation's influence on attitudes and actions. *American journal of Evaluation*, *24*(3), 293-314.

Herrenkohl, L. R., & Cornelius, L. (2013). Investigating elementary students' scientific and historical argumentation. *Journal of the Learning Sciences*, *22*(3), 413-461.

Herrmann-Abell, C. F., & Roseman, J. E. (2016). Comparing the year 3 and year 4 versions of Toward High School Biology. Retrieved from http://www.aaas.org/sites/default/files/THSB%20Research%20Summary%202016.pdf

Herold, J. (1974). Sputnik in American education: A history and reappraisal. *McGill Journal of Education/Revue des sciences de l'éducation de McGill*, *9*(002).

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for research in mathematics education*, *39*(4), 372-400.

Hochheimer, C. J., Sabo, R. T., Krist, A. H., Day, T., Cyrus, J., & Woolf, S. H. (2016). Methods for evaluating respondent attrition in web-based surveys. *Journal of medical Internet research*, *18*(11), e301.

Hodson, D. (2003). Time for action: Science education for an alternative future. *International journal of science education*, *25*(6), 645-670.

Hoerger, M. (2010). Participant dropout as a function of survey length in Internet-mediated university studies: Implications for study design and voluntary participation in psychological research. *Cyberpsychology, behavior, and social networking*, *13*(6), 697-700.

Hofstein, A., Scherz, Z., & Yager, R. E. (1986). What students say about science teaching, science teachers and science classes in Israel and the US. *Science Education*, *70*(1), 21-30.

Hollins, E. R. (2011). Teacher preparation for quality teaching. *Journal of Teacher education*, *62*(4), 395-407.

Holsti, O. R. (1969). Content analysis for the social sciences and humanities. *Reading. MA: Addison-Wesley (content analysis)*.

Hubber, P., Tytler, R., & Haslam, F. (2010). Teaching and learning about force with a representational focus: Pedagogy and teacher change. *Research in Science Education*, *40*(1), 5-28.

Hudson, T. (1991). A content comprehension approach to reading English for science and technology. *Tesol quarterly*, *25*(1), 77-104.

Huizinga, T., Handelzalts, A., Nieveen, N., & Voogt, J. M. (2014). Teacher involvement in curriculum design: Need for support to enhance teachers' design expertise. *Journal of curriculum studies*, *46*(1), 33-57.

Hurd, P. D. (2002). Modernizing science education. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *39*(1), 3-9.

Hwang, J., Choi, K. M., Bae, Y., & Shin, D. H. (2018). Do teachers’ instructional practices moderate equity in mathematical and scientific literacy?: An investigation of the PISA 2012 and 2015. *International Journal of Science and Mathematics Education*, *16*(1), 25-45.

Johnson-Freese, J. (2007). *Space as a strategic asset*. Columbia University Press.

Kazemi, E., & Hubbard, A. (2008). New directions for the design and study of professional development: Attending to the coevolution of teachers' participation across contexts. *Journal of teacher education*, *59*(5), 428-441.

Kelchtermans, G. (2009). Who I am in how I teach is the message: self-understanding, vulnerability and reflection. *Teachers and Teaching: theory and practice*, *15*(2), 257-272.

Kelly, A. E. (Ed.). (2003). The role of design in educational research [Theme issue]. Educational Researcher, 32(1).

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM education*, *3*(1), 1-11.

Kennedy, C. A., ... & Krajcik, J. S. (2015). Impact of project-based curriculum materials on student learning in science: Results of a randomized controlled trial. *Journal of Research in Science Teaching*, *52*(10), 1362-1385.

Kelchtermans, G. (2009). Who I am in how I teach is the message: Self-understanding, vulnerability and reflection. Teachers and Teaching: Theory and Practice, 15(2), 257-272.

Keller, T. E., & Pearson, G. (2012). A framework for K-12 science education: Increasing opportunities for student learning. *Technology and Engineering Teacher, 71*(5), 12-18. Retrieved from https://www.proquest.com/scholarly-journals/framework-k-12-science-education-increasing/docview/1010820027/se-2?accountid=11689

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM education*, *3*(1), 1-11.

Kim, J. S., & Sunderman, G. L. (2005). Measuring academic proficiency under the No Child Left Behind Act: Implications for educational equity. Educational Researcher, 34(8), 3–13.

Koller, J. R., Osterlind, S. J., Paris, K., & Weston, K. J. (2004). Differences between novice and expert teachers' undergraduate preparation and ratings of importance in the area of children's mental health. *International Journal of Mental Health Promotion*, *6*(2), 40-45.

Korstjens, I., & Moser, A. (2018). Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, *24*(1), 120-124.

Krajcik, J., McNeill, K. L., & Reiser, B. J. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science education*, *92*(1), 1-32.

Krajcik, J., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards. *Journal of Science Teacher Education*, *25*(2), 157-175.

Krippendorff, Klaus (2004). Content analysis. An introduction to its methodology. Thousand Oaks, CA: Sage.

Kuhlthau, C. C. (1991). Inside the search process: Information seeking from the user's perspective. *Journal of the American society for information science*, *42*(5), 361-371.

Kyriacou, C. (2001). Teacher stress: Directions for future research. *Educational review*, *53*(1), 27-35.

Ladson-Billings, G. (1992). Culturally relevant teaching: The key to making multicultural education work. *Research and multicultural education: From the margins to the mainstream*, 106-121.

LaDue, N. D., Libarkin, J. C., & Thomas, S. R. (2015). Visual representations on high school biology, chemistry, earth science, and physics assessments. *Journal of science education and technology*, *24*(6), 818-834.

Lauderdale-Littin, S., & Brennan, M. (2018). Evidence-based practices in the public school: The role of preservice teacher training. *International Electronic Journal of Elementary Education*, *10*(3), 369-375.

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of research in science teaching*, *29*(4), 331-359.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *36*(8), 916-929.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. International Journal of Education in Mathematics, Science and Technology, 1(3), 138-147.

Lee, I. (2011). Feedback revolution: what gets in the way?. *ELT journal*, *65*(1), 1-12.

Lee, O., & Buxton, C. (2008). Science curriculum and student diversity: A framework for equitable learning opportunities. *The Elementary School Journal*, *109*(2), 123-137.

Leshner, A. I., & Scherer, L. (2019). Critical steps toward modernizing graduate STEM education. *Issues in Science and Technology*, *35*(2), 46-49.

Licona, M. M. (2013). Mexican and Mexican-American children's funds of knowledge as interventions into deficit thinking: Opportunities for praxis in science education. *Cultural Studies of Science Education*, *8*(4), 859-872.

Lindsey, R. B., Nuri-Robins, K., Terrell, R. D., & Lindsey, D. B. (2018). *Cultural proficiency: A manual for school leaders*. Corwin Press.

Lotter, C. R., Thompson, S., Dickenson, T. S., Smiley, W. F., Blue, G., & Rea, M. (2018). The impact of a practice-teaching professional development model on teachers' inquiry instruction and inquiry efficacy beliefs. *International Journal of Science and Mathematics Education*, *16*(2), 255-273.

Mandal, S. K. D. (2018). Attributes of good teaching in engineering education in Indian subcontinent. *Sādhanā*, *43*(11), 1-12.

Matthews, M. R. (2000). *Time for science education: How teaching the history and philosophy of pendulum motion can contribute to science literacy* (Vol. 8). Springer Science & Business Media.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., & Tal, R. T. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of research in Science Teaching*, *41*(10), 1063-1080.

Marzano, R. J. (1999). Building Curriculum and Assessment around Standards. *High School Magazine*, *6*(5), 14-19.

Marzano, R. J. (2003). *What works in schools: Translating research into action*. ASCD.

Mathers, C., & Oliva, M. (2008). Improving Instruction through Effective Teacher Evaluation: Options for States and Districts. TQ Research & Policy Brief. *National comprehensive center for teacher quality*.

Maxwell, J. A. (2006). Literature reviews of, and for, educational research: A commentary on Boote and Beile's "Scholars before Researchers". *Educational researcher*, *35*(9), 28-31.

Mayring, P. (2000). Pensionierung als Krise oder Glücksgewinn?–Ergebnisse aus einer quantitativ-qualitativen Längsschnittuntersuchung. *Zeitschrift für Gerontologie und Geriatrie*, *33*(2), 124-133.

McClure, E. R., Guernsey, L., Clements, D. H., Bales, S. N., Nichols, J., Kendall-Taylor, N., & Levine, M. H. (2017). STEM Starts Early: Grounding Science, Technology, Engineering, and Math Education in Early Childhood. In *Joan Ganz Cooney center at sesame workshop*. Joan Ganz Cooney Center at Sesame Workshop. 1900 Broadway, New York, NY 10023.

McFadden, J. R., & Roehrig, G. H. (2017). Exploring teacher design team endeavors while creating an elementary-focused STEM-integrated curriculum. *International Journal of STEM Education*, *4*(1), 1-22.

McLaughlin, M. W., & Talbert, J. E. (1993). Contexts that matter for teaching and learning: Strategic opportunities for meeting the nation's educational goals.

McMillan, J. H. (2010). The practical implications of educational aims and contexts for formative assessment. In *Handbook of formative assessment* (pp. 41-58). Routledge.

McNeill, D. (2008). *Gesture and thought*. University of Chicago press.

McNeill, K. L., & Krajcik, J. (2008). Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student learning. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *45*(1), 53-78.

McTighe, J., & Wiggins, G. (2012). From common core standards to curriculum: Five big ideas. *The New Hampshire Journal of Education*, *16*, 25-31.

Mendelson, N. A. (2011). “Rulemaking, Democracy, and Torrents of E-Mail.” *George Washington Law Review* 79 (5): 1343–1380.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading research quarterly*, *39*(1), 38-70.

Moore III, J. L. (2005). Underachievement among gifted students of color: Implications for educators. *Theory into practice*, *44*(2), 167-177.

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). NGSS and the landscape of engineering in K-12 state science standards. *Journal of Research in Science Teaching*, *52*(3), 296-318.

National Commission on Excellence in Education. (1983). A nation at risk: The imperative for educational reform. *The Elementary School Journal*, *84*(2), 113-130.

National Research Council. (1995). *Virtual reality: scientific and technological challenges*. National Academies Press.

National Research Council. (2001). *Classroom assessment and the national science education standards*. National Academies Press.

National Research Council. (2007). Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, Committee on Science, Engineering, and Public Policy.

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, D.C.: Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education.

National Science Foundation (US). Directorate for Education, & Human Resources. (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology* (Vol. 1). National Science Foundation, Division of Undergraduate Education.

National Science Teachers Association. (1971). The Science Curriculum, The Science Teacher, and NSTA. *Science Teacher*.

Neidorf, T., Stephens, M., Lasseter, A., Gattis, K., Arora, A., Wang, Y., ... & Rahman, T. (2016). A Comparison between the Next Generation Science Standards (NGSS) and the National Assessment of Educational Progress (NAEP) frameworks in science, technology and engineering literacy, and mathematics. *National Center for Education Statistics*.

Newman Jr, W. J., Abell, S. K., Hubbard, P. D., McDonald, J., Otaala, J., & Martini, M. (2004). Dilemmas of teaching inquiry in elementary science methods. *Journal of Science teacher education*, *15*(4), 257-279.

Nestler, S., Thielsch, M., Vasilev, E., & Back, M. D. (2015). Will they stay or will they go? Personality predictors of dropout in an online study. *International Journal of Internet Science*, *10*(1), 37-48.

Nordine, J., Neumann, K., Fortus, D., Kubsch, M., & Krajcik, J. (2017). Exploring how middle school students use energy to explain phenomena. In *12th Conference of the European Science Education Research Association (ESERA), Dublin, Ireland*.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International journal of qualitative methods*, *16*(1), 1609406917733847.

Olson, J. K. (2018). The inclusion of the nature of science in nine recent international science education standards documents. *Science & Education*, *27*(7), 637-660.

Palloff, R. M., & Pratt, K. (2013). *Lessons from the virtual classroom: The realities of online teaching*. John Wiley & Sons.

Pellegrino, J. W., Wilson, M. R., Koenig, J. A., & Beatty, A. S. (Eds.). (2014). Developing assessments for the next generation science standards.

Perry, C. J., & Lawrence, A. J. (2017). Hurdles in basic science translation. *Frontiers in pharmacology*, *8*, 478.

Postareff, L. (2007). Teaching in higher education: from content-focused to learning-focused approaches to teaching.

Pruitt, S. L. (2014). The next generation science standards: the features and challenges. *Journal of Science Teacher Education*, *25*(2), 145–156.

Regan-Smith, M., Hirschmann, K., & Lobst, W. (2007). Direct observation of faculty with feedback: an effective means of improving patient-centered and learner-centered teaching skills. *Teaching and learning in medicine*, *19*(3), 278-286.

Reiser, B. J. (2013, September). What professional development strategies are needed for successful implementation of the Next Generation Science Standards. In *Invitational Research Symposium on Science Assessment* (pp. 1-22).

Reiser, B. J., Novak, M., & McGill, T. A. (2017). Coherence from the students' perspective: Why the vision of the framework for K-12 science requires more than simply "combining" three dimensions of science learning. In *Board on Science Education Workshop "Instructional Materials for the Next Generation Science Standards*.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of educational research*, *75*(2), 211-246.

Renn, O., Webler, T., Rakel, H., Dienel, P., & Johnson, B. (1993). Public participation in decision making: a three-step procedure. *Policy sciences*, *26*(3), 189-214.

Richert, A. E. (1990). Teaching teachers to reflect: A consideration of programme structure. *Journal of curriculum studies*, *22*(6), 509-527.

Ricketts, M. (2018). No more bullet points: Research-based tips for better presentations. *Professional Safety*, *63*(09), 34-43.

Ring, E. A., Dare, E. A., Crotty, E. A., & Roehrig, G. H. (2017). The evolution of teacher conceptions of STEM education throughout an intensive professional development experience. *Journal of Science Teacher Education*, *28*(5), 444-467.

Roberts, D. A. (2013). Scientific literacy/science literacy. In *Handbook of research on science education* (pp. 743-794). Routledge.

Robinson, J. P., & Lubienski, S. T. (2011). The development of gender achievement gaps in mathematics and reading during elementary and middle school: Examining direct cognitive assessments and teacher ratings. *American Educational Research Journal*, *48*(2), 268-302.

Rodriguez, A. J. (2015). What about a dimension of engagement, equity, and diversity practices? A critique of the next generation science standards. *Journal of Research in Science Teaching*, *52*(7), 1031-1051.

Roseman, J. E., Herrmann-Abell, C. F., & Koppal, M. (2017). Designing for the next generation science standards: Educative curriculum materials and measures of teacher knowledge. *Journal of Science Teacher Education*, *28*(1), 111-141.

Rubba, P. A. (1977). The development, field testing and validation of an instrument to assess secondary school students understanding of the nature of scientific knowledge. Indiana University.

Rubba, P. A., & Andersen, H. O. (1978). Development of an instrument to assess secondary school students understanding of the nature of scientific knowledge. *Science education*, *62*(4), 449-458.

Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional science*, *18*(2), 119-144.

Schmeichel, M. (2012). Good teaching? An examination of culturally relevant pedagogy as an equity practice. *Journal of curriculum Studies*, *44*(2), 211-231.

Schmidt, W., Houang, R., & Cogan, L. (2002). A coherent curriculum. *American Education*, 1-17.

Schmidt, W H., Wang, H. C, & McKnight, C. C. (2005). Curriculum coherence: An examination of U.S. mathematics and science content standards from an international perspective. Journal of Curriculum Studies, 37(5), 525-559.

Schneider, R. M., & Krajcik, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. *Journal of science teacher education*, *13*(3), 221-245.

Schrier, K. (2006). Using augmented reality games to teach 21st century skills. In *ACM Siggraph 2006 Educators Program* (pp. 15-es).

Schwab, K. (2018, November). The global competitiveness report 2018. In *World Economic Forum* (Vol. 671).

Seels, B. B., & Richey, R. C. (2004). Instructional technology: The definition and domains of the field. Washington, DC: AECT.

Seiler, G. (2013). New metaphors about culture: Implications for research in science teacher preparation. *Journal of Research in Science Teaching*, *50*(1), 104-121.

Seljan, S. (2011). Translation technology as Challenge in education and business. *Informatologia*, *44*(4), 279-286.

Sellmann, D., Beckmann, V., Panzlaff, S., & Menzel, S. (2019). Zoo educators face common and specific demands and resources: an application of the JD-R model. *Environmental Education Research*, *25*(1), 92-114.

Seymour, E. (2002). Tracking the processes of change in US undergraduate education in science, mathematics, engineering, and technology. *Science Education*, *86*(1), 79-105.

Shapiro, G., & Markoff, J. (1997). A matter of definition. *Text analysis for the social sciences: Methods for drawing statistical inferences from texts and transcripts*, *1*, 9-34.

Shymansky, J. A., Kyle Jr, W. C., & Alport, J. M. (1983). The effects of new science curricula on student performance. *Journal of research in Science Teaching*, *20*(5), 387-404.

Siebert-Evenstone, A. L. (2021, November). A Qualitative Analysis of Connection-Making in the NGSS. In *International Conference on Quantitative Ethnography* (pp. 95-113). Springer, Cham.

Sinclair, J., Cuthbert, D., & Barnacle, R. (2014). The entrepreneurial subjectivity of successful researchers. *Higher Education Research & Development*, *33*(5), 1007-1019.

Siskin, L. S. (2014). *Realms of knowledge: Academic departments in secondary schools*. Routledge.

Sleeter, C., & Carmona, J. F. (2017). *Un-standardizing curriculum: Multicultural teaching in the standards-based classroom*. Teachers College Press.

Sleeter, C. E., & Zavala, M. (2020). *Transformative ethnic studies in schools: Curriculum, pedagogy, and research*. Teachers College Press.

Smith-Senger, E. (1998). Reflective reform in mathematics: The recursive nature of teacher change. *Educational Studies in Mathematics*, *37*(3), 199-221.

Snell, J., & Lefstein, A. (2018). "Low ability," participation, and identity in dialogic pedagogy. *American Educational Research Journal, 55*(1), 40-78.

Solomon, P. G. (Ed.). (2009). *The curriculum bridge: From standards to actual classroom practice*. Corwin Press.

Songer, N. B., Lee, H. S., & McDonald, S. (2003). Research towards an expanded understanding of inquiry science beyond one idealized standard. *Science Education*, *87*(4), 490-516.

Soroka, S. N., & Wlezien, C. (2010). *Degrees of democracy: Politics, public opinion, and policy*. Cambridge University Press.

Spillane, J. P. (1998). A cognitive perspective on the role of the local educational agency in implementing instructional policy: Accounting for local variability. *Educational Administration Quarterly*, *34*(1), 31-57.

Squires, D. A. (2005). Aligning and balancing the standards-based curriculum. Thousand Oaks, CA: Corwin Press.

Stein, S. G. (2000). *Equipped for the future content standards: What adults need to know and be able to do in the 21st century*. National Institute for Literacy.

Stobart, G. (2006). The validity of formative assessment. *Assessment and learning*, 133-146.

Supovitz, J. A. (2001). Chapter V: Translating Teaching Practice into Improved Student Achievement. *Teachers College Record*, *103*(8), 81-98.

Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2019). Understanding teacher shortages: An analysis of teacher supply and demand in the United States. *Education Policy Analysis Archives*, *27*(35).

Tomlinson, C. A. (2000). Reconcilable differences: Standards-based teaching and differentiation. *Educational leadership*, *58*(1), 6-13.

Tomlinson, C. A., & McTighe, J. (2006). *Integrating differentiated instruction & understanding by design: Connecting content and kids*. ASCD.

Torrance, H. (1993). Formative assessment: Some theoretical problems and empirical questions. *Cambridge journal of education*, *23*(3), 333-343.

Trochim, W., & Donnelly, J. P. (2008). The research methods knowledge base Mason. *OH: Cengage Learning*.

United States. National Commission for the Protection of Human Subjects of Biomedical, & Behavioral Research. (1978). *The Belmont report: ethical principles and guidelines for the protection of human subjects of research* (Vol. 2). Department of Health, Education, and Welfare, National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research.

Valenzuela, A. (2002). Reflections on the subtractive underpinnings of education research and policy. *Journal of Teacher Education*, *53*(3), 235-241.

Van den Hoonaard, W. C. (1997). *Working with sensitizing concepts: Analytical field research*. Thousand Oaks (Calif.): Sage, 1997.

Vitiello, V. E., Pianta, R. C., Whittaker, J. E., & Ruzek, E. A. (2020). Alignment and misalignment of classroom experiences from Pre-K to kindergarten. *Early Childhood Research Quarterly*, *52*, 44-56.

Vosniadou, S. (2012). Reframing the classical approach to conceptual change: Preconceptions, misconceptions and synthetic models. In *Second international handbook of science education* (pp. 119-130). Springer, Dordrecht.

Wallace, T., & Brand, B. R. (2012). Using critical race theory to analyze science teachers culturally responsive practices. *Cultural Studies of Science Education*, *7*(2), 341-374.

Washington, W. M., Barish, B. C., Droege-Meier, K. K., & Ford, K. M. (2006). National Science Board.

Webb, S. A. (2006). *Social work in a risk society: Social and political perspectives*. Macmillan International Higher Education.

Weiner, M. F. (2016). Racialized classroom practices in a diverse Amsterdam primary school: The silencing, disparagement, and discipline of students of color. *Race Ethnicity and Education*, *19*(6), 1351-1367.

Weiss, I. R., Pasley, J. D., Smith, P. S., Banilower, E. R., & Heck, D. J. (2003). *Looking inside the classroom: A study of K–12 mathematics and science education in the United States*. Chapel Hill, NC: Horizon Research.

Wieringa, N., Janssen, F. J., & Van Driel, J. H. (2011). Biology teachers designing context-based lessons for their classroom practice—the importance of rules-of-thumb. *International Journal of Science Education*, *33*(17), 2437-2462.

Wiggins, G. P., & McTighe, J. (2011). The understanding by design guide to creating high-quality units. ASCD. Chicago.

Wilde, M. J. (2018). Complex religion: Interrogating assumptions of independence in the study of religion. *Sociology of Religion*, *79*(3), 287-298.

Wiliam, D. (2011). What is assessment for learning?. *Studies in educational evaluation*, *37*(1), 3-14.

Williams, H. T., McMurray, J. R., Kurz, T., & Lambert, F. H. (2015). Network analysis reveals open forums and echo chambers in social media discussions of climate change. *Global environmental change*, *32*, 126-138.

Wilson, C. (2015). Hour of code---a record year for computer science. *ACM Inroads*, *6*(1), 22-22.

Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *47*(3), 276-301.

Windschitl, M., McDonald, M., Kazemi, E., Kelley-Petersen, M., Mikolasy, K., Thompson, J., & Valencia, S. W. (2014). Practice makes practice: Learning to teach in teacher education. *Peabody Journal of Education*, *89*(4), 500-515.

Windschitl, M., Schwarz, C., & Passmore, C. (2014). Supporting the implementation of the Next Generation Science Standards (NGSS) through research: Pre-service teacher education.

Yackee, S. W. 2005. “Sweet-Talking the Fourth Branch: The Influence of Interest Group Comments on Federal Agency Rulemaking.” *Journal of Public Administration Research & Theory* 16 (1): 103–124.

Yin, R. K. (2012). Case study methods.

You, H. S. (2017). Why teach science with an interdisciplinary approach: history, trends, and conceptual frameworks. *Journal of Education and Learning*, *6*(4), 66-77.

Zangori, L., & Forbes, C. T. (2013). Preservice elementary teachers and explanation construction: Knowledge-for-practice and knowledge-in-practice. Science Education, 97(2), 310–330.

APPENDIX A: Example of analytical memo

Several stakeholders had very specific answers to the second research question concerning how to directly improve the NGSS. From this it makes sense to look at the feelings behind what stakeholders are saying. If they have a specific outcome that they wish to see, what happens to be their driving force behind what they are asking for? Can these suggestions be connected to codes?

MIDDLE SCHOOL:

In my opinion I feel as if there should be a standard that comes before this.—*Disjointed progression of standards*

One that simplifies gravitational interactions. Then mass should have already been addressed earlier. It should be a standard in which they just develop an experiment to prove that fields exist rather than focusing on the assessment of the design.—*Standard remains too specific, needs more help, resources, student knowledge*

Create a model that shows relationships between kinetic energy and particle motion during temperature fluctuations.—*Clarity with example*

Supporting the claim that digitized signals are more reliable ways to encode and transmit information over analog is fine.—*Changing verbiage of standard for clarity and simplicity*

Maybe construct an explanation for how technical information in digital form is a more reliable way to transmit information than analog signals, using scientific data to support the claim. "...interacting subsystems" is a bit wordy; could this standard change to, "...interacting body systems..." and/or mention the levels of organization from cells to body with an assessment boundary being that specific tissues and organ functions are not necessary but that students should know that tissues make organs and organs make organ systems.—*How do I teach this standard better? Better words, more examples, more specificity? How can I do this on the level of my students?*

Use an argument supported by evidence for how the body is a system of interacting subsystems composed of a group of cells that contribute to the system functioning as a whole.—*Arguing through examples*

Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter into and out of organisms. or example, you could show a potential progression—*Change complexity of SEP*

Using Bloom's Taxonomy (not THESE necessarily, but something like this)- ESS1-1 Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. ESS1-1a- Define and describe rotation and revolution as related to objects' movement in space ESS1-1b- Predict lunar phases based on data provided (pictorial or numerical) ESS1-1c- Evaluate models of the Earth-sun-moon system that show patterns pf lunar phases, eclipses, or seasons ESS1-1d- Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.—*Use of example, reword. Use of scaffolding for students, break apart standard*

Majority of middle school suggestions revolve around physical science—no specific elementary?

HIGH SCHOOL:

Use mathematical representations to support the conservation of momentum: That the total momentum of a system before and after a collision is equal in elastic collisions, inelastic collisions and explosions. Where a system is defined as two objects with a defined mass and velocity.—*Defining what is to have a mathematical representation*

The mathematical representations should also be specified: Elastic collisions: (m1v1+m2v2)before = (m1v1+m2v2)after inelastic collisions: (m1v1+m2v2)before = (m1+m2)Vf explosions: 0 = (m1v1+m2v2)—*Use of example adds to greater specificity and a scaffold for students*

Construct and revise an explanation based on evidence that matter and energy cycle within and without of aerobic and anaerobic conditions.—*Use of simplicity and specificity with science language*

This clarifies that matter and energy always cycle, now we can get to the root of how and why they cycle within and between aerobic and anaerobic conditions.—*Teacher naivety with their simplicity?*

APPENDIX B: First Cycle Coding Results

Descriptive Code	***Times Coded***
Clarify with examples	68
Clarity	61
Too complex	39
Move to 7th	25
Teachers need tools/resources	25
Move standard	18
Break apart standard	18
Verbiage unclear	16
Disjointed standard progression	15
Remove standard	15
Reword standard	15
Add more to standard	14
Move to 6th	14
Unclear to teachers	13
Move to 8th	12
Expectations are too high	11
Students need prior knowledge	10
Real world relevance	9
Combine standards	8
No prior knowledge	8
Standard is too extensive	8
Difficult to teach	7
More SEP options	7
Teachers need more instruction	7
Redundancy	6
Reword verbs	6
Student relevance	6
Students have experience	6
Clarify intent of standard	5
Focus is too specific	5
Frustration with the committee	5
No time to achieve standard	5
Standard is too broad	5

Descriptive Code	Times Coded
Student understanding mathematical representation	5
Tier the standard for students	5
Too abstract for students	5
Difficult to assess	4
Kentucky specific teaching	4
Not significant or relevant	4
Progression of standards	4
Questions about assessment	4
Standard has hidden prior knowledge	4
Students need background knowledge	4
Additional specific knowledge	3
Combine human impact standards	3
In my experience no one understands	3
Move standard up	3
No money for resources	3
Options of displaying learning	3
Same level as other laws	3
Similar to other standards	3
Standard depth is too great	3
Students struggle with SEP	3
Temporary covid protocols	3
Textbooks not helpful	3
Too challenging for students	3
Too difficult for students	3
Add more to SEP	2
Clarify assessment boundaries	2
Clarifying the intent of the standard	2
Early students should understand	2
Forced subject matter	2
FOSS curriculum not aligned	2
Highly relevant standard	2
Include 1st and 2nd law	2
Modeling SEP not necessary	2
Move standard down	2
Move standard to 4th	2
Need more detail	2
PE has too much	2
PE should be earlier	2
Science community disagreement	2

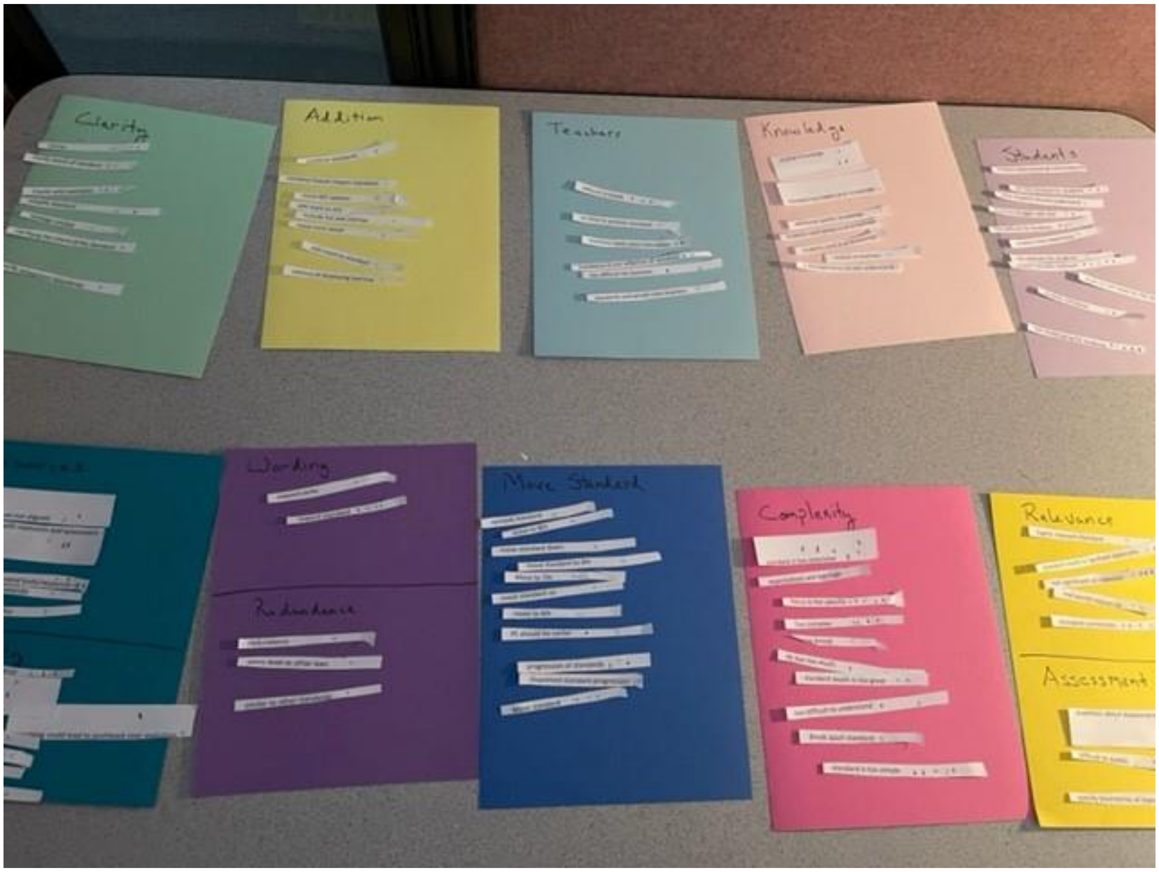
Descriptive Code	***Times Coded***
Science not taught in district	2
SEP is difficult for standard	2
Simplify standard	2
Specify boundaries of standard	2
Standard connection	2
Standard is too simple	2
Standard needs to be more applicable	2
Standards overwhelm new teachers	2
Students become confused	2
Students not ready for this depth	2
Support standard with resources and assessment	2
Teaching could lead to pushback over evolution	2
Too difficult for teachers	2
Too difficult to understand	2
Translation is not reflective of standard	2
Add responses of social systems to standard	1
Add to standard for clarity	1
Additional standard needed with examples	1
Appropriate standard for middle school	1
As written sounds elementary	1
Assessment boundary should go deeper	1
Beyond the scope of projects	1
Bias material not relevant to students	1
Curriculum (FOSS) does not represent the standard	1
Declining prior knowledge	1
Disagreement with embryology	1
Disservice to students	1
Early teachers need more supports	1
Elementary level expectations, more challenging	1
Eliminate part of the standard	1
Eliminate verb of the standard	1
Enough to stand on its own as a standard	1
Example of standard for clarity	1
Extension project	1
Frustration with models	1
Graph representations on all grades	1
Ignore the standard	1
Intent goes beyond the scope of the standard	1
Is this standard taught	1

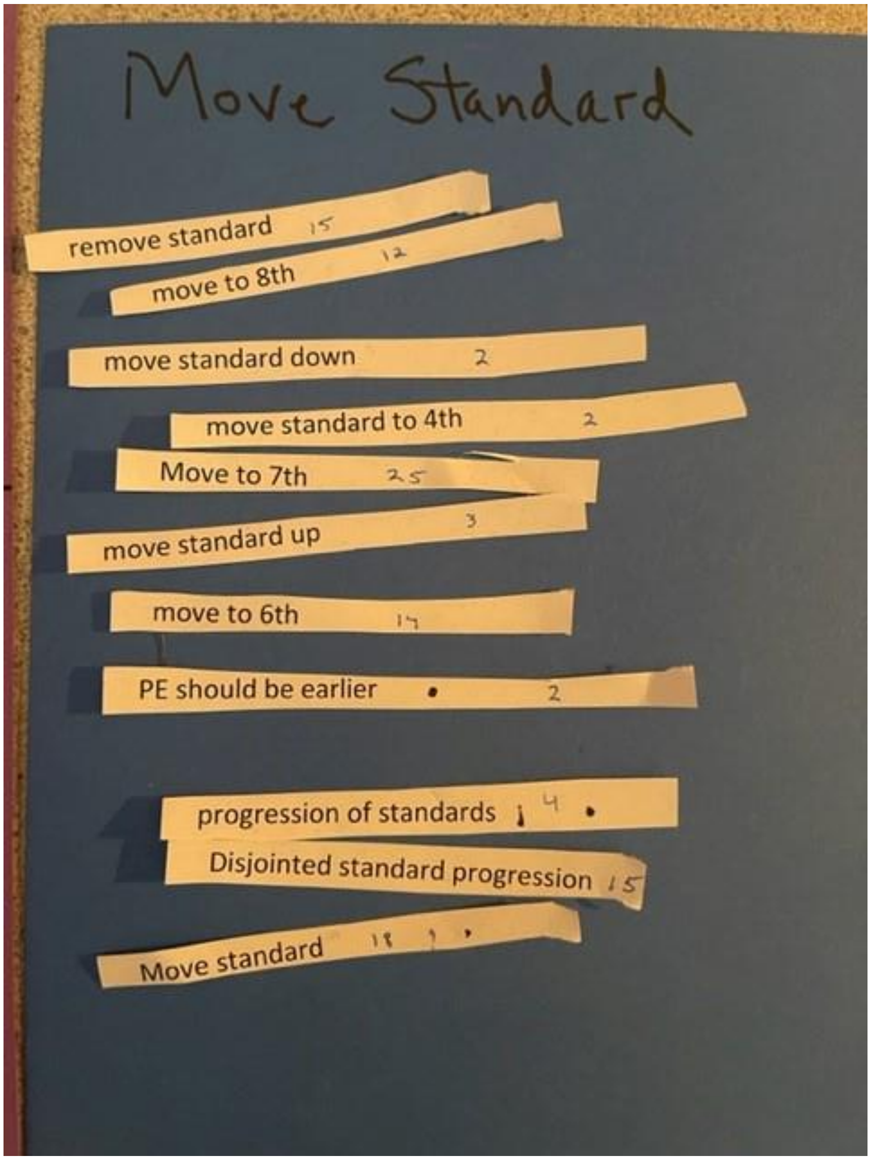
Descriptive Code	***Times Coded***
Like the standard	1
Make up for missing content	1
Making connections	1
Many not teaching correctly	1
More appropriate for older students	1
More details of expectations	1
More explanation through specifics	1
More important standards	1
More specific focus	1
Move standard due to relevance	1
Narrow the standard	1
Need more focus	1
Need more supports, examples and time	1
Need multiple experiences	1
NIMBY green	1
No time for proficiency	1
No time to teach	1
Not done in real world	1
Not enough content knowledge	1
Not relevant to adults	1
Not relevant to science	1
Overwhelm students and teachers	1
PE limits teacher ability	1
Personal connection to science	1
Pick a side specific or broad	1
Rewrite standard for all teachers	1
Science and social studies argumentation similar	1
Science not taught in elementary	1
SEP does not work for students	1
SEP needs more detail	1
Skills repeated from earlier grades	1
Social justice aspects internationally	1
Specific task only	1
Specific teaching outside PE	1
Specify more on standard	1
Standards and beliefs not assimilated	1
Standard can go deeper	1
Standard confusing as written	1
Standard does not integrate	1

Descriptive Code	*Times Coded*
Standard does not relate	1
Standard does not fit in unit	1
Standard is obscure	1
Standard is too field specific	1
Standard is not appropriate	1
Standard not taught	1
Standard progression can be improved	1
Standards all need to be changed	1
Standards are too deep	1
Standards cannot be fully realized	1
Standards not friendly	1
Structure is not realistic	1
Student clarity	1
Student confusion	1
Student expectation based on math	1
Student misconceptions	1
Student satisfaction comes from execution of plan	1
Student vocabulary	1
Students can't learn IEP's	1
Students give up	1
Students have difficulty due to fear of failure	1
Students will not attempt	1
Suggest cell division as a standard	1
Support material needed	1
Supported students gain proficiency	1
Take out questions simplify	1
Teacher belief that lesson are necessary	1
Teachers not teaching this standard consistently	1
Tie back to reinforce previous standards	1
Timing of standard	1
To understand need to use resources--this is not necessary	1
Too in depth	1
Too many interpretations	1
Too much information to teach	1
Too much math focus	1
Too narrow of a topic	1
Too specific not based on phenomena	1
Unable to push students to this level	1
Understand why this law was included	1

Descriptive Code	***Times Coded***
Use modeling SEP	1
Vagueness makes teaching flexible	1
Vocabulary of standard	1
Where can I find resources	1
Worth of standard, specific	1
TOTAL	**744**

APPENDIX C: Display of Axial Sorting




Move Standard
remove standard 15
move to 8th 12
move standard down 2
move standard to 4th 2
Move to 7th 25
move standard up 3
move to 6th 14
PE should be earlier 2
progression of standards 4
Disjointed standard progression 15
Move standard 18

APPENDIX D: Axial codes with descriptive codes linked by

Axial Code	Descriptive code with ***modifier***
Relevance	*it is a* highly relevant standard (2) *but* standard needs to be more applicable (3) *although it is* not significant or relevant (7) *but no* real world relevance (10) *without* standard connection (6)
Assessment	*we have* questions about assessment (4) *because it is* difficult to assess (4) *you should* specify the boundaries of standard (3)
Complexity (41)	*because* standard is too extensive (13) *because* expectations are too high (11) *because* focus is too specific (9) *the* standard is too broad (5) *and* PE has too much (3) *standard is* too difficult to understand (3) standard depth is too great (4) *could you* break apart standard (18) *not true* standard is too simple (6) *Please* simplify standard (3)
Wording	*is unclear* reword standard (18) *is unclear* reword verbs (6)
Redundancy (6)	*it is the* same level as other laws (3) *truly* similar to other standards (3)
Resources	*because* FOSS curriculum not aligned (3) *to* support standard with resources and assessment (5) *We* teachers need tools/resources (28) *there is* no money for resources (3) *since* textbooks are not helpful (3)

Axial Code	**Descriptive code with *modifier***
Locality	*it is* forced subject matter (6)
	this teaching could lead to pushback over evolution (3)
	because science not taught in district (4)
	using Kentucky specific teaching (4)
	difficult due to temporary Covid protocols (3)
	showing frustration with the committee (5)
	even the science community disagreement (2)
Move Standard (20)	*it should* move to 8th (12)
	it should move to 6th (14)
	it should move to 7th (25)
	it should move to 4th (2)
	just remove standard (15)
	due to a disjointed standard progression (15)
	perhaps move standard up (3)
	perhaps move standard down (2*)*
	there is a poor progression of standards (6)
	so the PE should be earlier (3)
Teachers	*standard is* too difficult for teachers (3)
	standard is difficult to teach (9)
	teachers' need more instruction (8)
	teachers' translation is not reflective of standard
	have no time to achieve standard (5)
	believe standards overwhelm new teachers (2)
Clarity (63)	*you can* clarify the intent of standard (8)
	you can clarify with examples (71)
	you can clarify assessment boundaries (2)
	because the verbiage unclear (16)
Addition (14)	*by* combine standards (8)
	by combine human impact standards (3)
	to include 1st and 2nd law (2)
	Providing more SEP options
	including more options of displaying learning (3)
	to add more to SEP (2)
	because I need more detail (2)

Axial Code	**Descriptive code with *modifier***
Knowledge	*there is* no prior knowledge (10)
	because standard has hidden prior knowledge (4)
	requires additional specific knowledge (3)
	even students need background knowledge (4)
	as it is unclear to teachers (13)
	for students need prior knowledge (10)
	For in my experience no one understands (3)
Students	*Trying* understanding mathematical representation (6)
	need to tier the standard for students (6)
	even the early students should understand (2)
	will struggle with SEP (4)
	for it is too difficult for students (5)
	as no students have experience (6)
	realize standard is too abstract for students (5)
	are not ready for this depth (2)
	will become confused (7)
	see no relevance (7)
	find it too challenging for students (7)

Words in italics are researcher modifiers to connect axial code to descriptive code. Numbers in parentheses refer to how many times the axial or descriptive code was repeated during the first coding cycle.

CURRICULUM VITAE

Trzaskus, Matthew D.
3126 Wynbrooke Circle, Louisville, KY, 40241 | 502-500-1987 | m0trza01@louisville.edu

EDUCATION

University of Louisville, Louisville, KY
PhD Curriculum and Instruction **2022**
Current 4.0 GPA. Focus on middle and secondary education including:

- Students' use of technology in the classroom as a culturally relevant practice.
- Students' use of models and their effectiveness on conceptual change in learning science.
- Culturally relevant curricula design and implementation in an effort to close opportunity gaps.
- Qualitative root cause analysis of teacher feedback regarding implementation of standards.
- Heavily weighted class structure in research design and implementation, including multivariate educational statistical analysis and qualitative research methodologies.
- Presented University of Louisville Celebration of Teaching and Learning 2019.
- Co-presented at National Association for Research in Science Teaching (NARST) 2019.
- Presented Science Educators for Equity, Diversity and Social Justice (SEEDS) on Fostering Social Justice in Science through Sport, and its challenges.
- Received an internal grant for a research project to fund social justice in the high school biology classroom.

University of Louisville, Louisville, KY
M.A. Teaching **2017**
Graduated with 4.0 GPA.

- Participated in the University of Louisville's CAEP audit as an Alternative Certification representative.
- Pursued and completed degree while working full time and raising a family.

Clemson University, Clemson, SC
B. S. Biological Sciences **2001**

- Graduated in three years.
- Member of National Society of Collegiate Scholars and Calhoun Honors College.
- Tutored Biology, Chemistry, Physiology, and Biochemistry for the Student Athlete Enrichment Program.
- Received Tutor of the Year award in 2000.

TEACHING EXPERIENCE

VanHoose Education Center, JCPS, Louisville, KY
Multi-Tiered Systems of Support (MTSS) Resource Teacher--High School Zone 2020-present

- Provided a variety of professional development sessions in person and virtually for educators and administrators focusing on high yield instructional practices.
- Aided school representatives in the development and implementation of progress monitoring tools for tiered instructional supports.
- Guided schools in identifying areas of improvement through needs assessments and implementation plans designed to fulfill identified needs.
- Co-wrote instructional films for the district focusing on racial relationships and racial conversations.
- Obtained consultant certification on professional teaching license.
- Created district modules of high yield pedagogical practices that focused on accelerating learning post pandemic.
- Lead MTSS Team members in the creation and implementation of high yield instructional practices to be delivered to a cohort of alternative certification teachers, in conjunction with the University of Louisville.
- Facilitated team development through presenting the benefits of a flipped classroom model during virtual learning.

- Created culturally responsive and early childhood considerations for high yield practices that fit specifically with behavioral system support.
- Collaborated with team members to create fidelity measures for pedagogical modes of instruction.
- Worked across district level resource teams to provide training and support responding to school needs.
- Co-created modeling and observation protocols for teachers to be used by Academic Coaches to build capacity on best practices.

University of Louisville College of Education and Human Development
Adjunct faculty **2019-present**

- Taught undergraduates and graduate students interested in pursuing a career in education.
- Specialized in lesson development, scaffolding, and differentiation of multiple contents and levels.
- Taught alternative certification graduate students who were employed by JCPS and other local area districts.
- Supported students in creation of culturally responsive pedagogical practice for diverse learners.
- Emphasized the importance of combining behavioral management plans with academic curriculum.

Seneca High School, JCPS, Louisville, KY
Teacher—Anatomy & Physiology, Biology, Chemistry, and Forensic Science **2015-2020**

- Developed curriculum, syllabus, and overall course structure for both Anatomy & Physiology and Forensic Science at the school level.
- School leader for Racial Equity Committee. Responsible for student and teacher racial relations and sense of student belonging within the school.
- District Facilitator for Equity Literacy through JCPS and the Department of Equity and Inclusion.

- District Facilitator for Culturally Responsive Teaching and the Brain.
- District Facilitator for Poverty and the Brain.
- District Co-facilitator for Professional Development in Emotional Intelligence and Adolescent Development.
- Science department interim chair including budgeting for department resources and equitable allocation of grant funds.
- District Co-facilitator for Muslim Voices in the Schools through the Department of Equity and Inclusion.
- Member of JCPS's inaugural Seeking Educational Equity and Diversity (SEED) cohort.
- Facilitated school-wide training on Emotional Intelligence.
- Chosen as faculty representative for project based learning cohort.
- Chosen as content representative for Law advisory Committee for transition readiness due to past career experience.
- Chosen to be a member of SBDM Council in 2018-2020.
- Chosen to be a member of BSCS STeLLa cohort for JCPS Biology educators.
- Chosen to be content representative at CTE educational conference in Anaheim, CA, 2019.
- Member of the team receiving the KDE award for educators for creating effective PLCs in 2015.
- Guest speaker for Priority Schools Institute for JCPS.
- Created the school's collective commitments in alignment with school and district mission.
- Member of educational equity and budget committees 2017-2020.

RELATED EXPERIENCE

Kentucky State Police—Louisville, KY

Forensic Scientist Specialist **2006 – 2015**

- Provided support to law enforcement agencies in solving violent crimes associated with the transfer of DNA evidence, bloodstain patterns, and crime scene reconstructions.
- Testified as a court recognized expert in the field of forensic biology more than 90 times.
- Member of the Midwestern Association of Forensic Scientists (MAFS) during the tenure.
- Assisted in laboratory's accreditation through the International Organization for Standardization/ American Society of Crime Lab Directors (ISO/ASCLD)
- Member of the Jefferson County Sexual Assault Response Team (SART) 2012-2014.
- Principal investigator in the efficacy of cleaning and sterilizing of laboratory equipment; leading to statewide changes in protocols.
- Received letter of commendation for research concerning identification of spermatozoa in 2007.
- Guest speaker for Hardin County Public Schools, Citizen's Police Academy various state locations, Louisville Metro Police Department—Homicide, Sex Crimes, and Robbery Units.

PUBLICATIONS

- McFadden, J. Tinnell,T., Trzaskus, M., Tretter, T., & Robinson, B. (in review) Enhancing K-8 Teachers' Capacity to Develop MultiDimensional, Formative Science Assessments: Assessing the Assessments; Applied Educational Measurement.
- Trzaskus, M., and Mark, S.L. (in review) Basketball and Evolution; International Society for Technology in Education.
- Mark, S. L., Trzaskus, M., Archer, L., & Azmani, P. (*in press*). *Fostering social connectedness and interest in science through sports.* In Alberto J. Rodriguez & Regina Suriel (Eds.). Supporting

STEM education with limited resources: Research-based and practical suggestions for advocacy and transformative change. Springer.

MEMBERSHIPS

Jefferson County Teachers Association
National Science Teachers Association